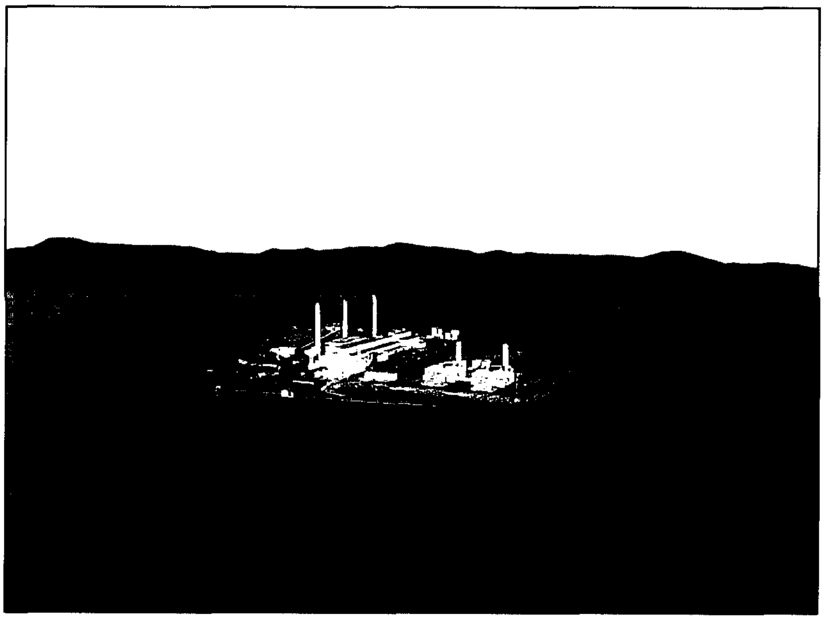
The Hongkong Electric Co., Ltd.
香港電燈有限公司

Environmental Impact Assessment of a 1,800MW Gas-Fired Power Station at Lamma Extension
Second Technical Annex



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ERM

FINAL REPORT

The Hongkong Electric Co., Ltd.

Environmental Impact Assessment of a 1,800MW Gas-Fired Power Station at Lamma Extension : *Second Technical Annex*

8 February 1999

Reference C1830

For and on behalf of
Environmental Resources Management

Approved by: Freeman Cheung

Signed:

Position: Deputy Managing Director

Date: 8 February 1999

EIA Report Organisation

The Report of the EIA Study of HEC's 1800MW New Power Station at Lamma Extension is presented as five volumes of which this is the *Second Technical Annex.*

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Volume 1:

- Part A of the EIA Report - Introduction
- Part B of the EIA Report - The New Power Station

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Volume 2:

- Part C of the EIA Report - The Transmission System
- Part D of the EIA Report - The Gas Pipeline
- Part E of the EIA Report - Assessment of Cumulative Impacts
- Part F of the EIA Report - Environmental Monitoring and Audit
- Part G of the EIA Report - Implementation Schedule
- Part H of the EIA Report - Overall Summary & Conclusions

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The First Technical Annex

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1 Introduction

In 1994 Hong Kong Electric Company (HEC) commissioned Environmental Resources Management-Hong Kong (ERM) to conduct a comprehensive site search for the new 1800 MW power station. Site selection criteria were that the potential site should have minimum impact on existing environmental resources, be feasible in terms of engineering, maritime and navigation requirements and be financially justifiable. By detailed assessment in terms of, among others, planning, physical impacts on landscape, ecology, air quality and water quality a limited number of possible locations has been identified.

In order to support the selection of one of the potential sites for Environmental Impact Assessment, predictive mathematical models were applied. In 1997 ERM commissioned WL | Delft Hydraulics to carry out a thermal plume modelling study for the Hong Kong waters west of Lamma Island and south-east of Lantau Island. The principal objective of that study was to investigate the effects of cooling water discharges for several potential sites of a new power station by means of mathematical modelling. The study was part of the Stage I of the Environmental Impact Assessment (EIA) study and was reported in (Delft Hydraulics, 1997b).

In the present project ERM commissioned WL | Delft Hydraulics to perform mathematical modelling for Stage II of the EIA In Stage II detailed modelling will be carried out of the impacts of the construction and operation of a new power station on a reclamation immediately to the south of the existing power station at Lamma Island. Modelling for the operational phase will consist of simulations of hydrodynamic conditions and the discharge of cooling water. Water quality modelling of sediment dispersion will be carried out to assess the impacts during the construction phase.

This report describes one of the modelling activities related to the operation phase, namely the thermal modelling for a new power station. Three scenarios have been examined:

- The existing situation, describing the Lamma Island power station.
- The situation with a new (extended) Lamma Island power station (reclamation 1 in Figure 2.1.3).
- The situation with a new power station (reclamation 1) and with a proposed site for the Waste-to-Energy Incineration Facility (reclamation 2 in Figure 2.1.3).

For the same three situations a hydrodynamic assessment on flow changes due to the reclamations has been carried out recently, see (Delft Hydraulics, 1998c).

In this report the thermal plume modelling for Lamma Island site of the new power station is described. By using the detailed model described in (Delft Hydraulics, 1998a) the dispersion of heat has been modelled. The same methodology has been applied as in the thermal plume modelling for a new Hong Kong power station in Stage I of the EIA (Delft Hydraulics, 1997). The dispersion modelling to be carried out in the present project will yield more detailed information than in Stage I, because of the use of a higher model resolution. The new detailed model has been developed specifically for the area near Lamma Island.

The plume dispersion has been modelled together with the flows and the salinities. For the three scenarios simulations the size of the thermal spreading and the way it is taken with the currents has been examined. For all scenarios a neap tide and spring tide period for both a wet and a dry season situation have been simulated. The 2°C temperature increase zone has been computed. This involves all grid points for which the maximal temperature during the whole simulation is more than 2°C higher than the ambient temperature. There are no other specific criteria which determine the acceptability of the thermal plume discharges. This report does not determine whether the site is acceptable in terms of the impacts associated with the discharge.

In Chapter 2 the Lamma Island detailed model is described, which forms the basis of all simulations. Next, the operation of the Lamma Island power station and its consequences with respect to mathematical modelling are discussed. In Chapter 3 the numerical results for the wet season simulations are presented, whereas Chapter 4 is devoted to the dry season modelling. Finally, Chapter 5 contains the conclusions.

2 Introduction to thermal modelling

2.1 Lamma Island detail model

In order to enable more accurate hydrodynamic and water quality modelling than performed in Stage I of the EIA for a new power station, a new hydrodynamic detailed model for the Lamma Island region has been set up and validated (Delft Hydraulics, 1998b). In Figure 2.1.1 the grid of this detailed model is shown. Unlike in Stage I, which only focused on the area west of Lamma Island, the model has incorporated detail in the East Lamma Channel and in the area south of Lamma Island. These two areas will be of interest to the water quality modelling. In comparison to the Lamma Island model of Stage I, the new detailed model has slightly more resolution west of Lamma Island (approximately 100 m versus 150 m) and much more resolution in East Lamma Channel and south of Lamma Island. A higher resolution is possible because the new model has concentrated on the area around Lamma Island, which yields a smaller model area in comparison to the Stage I which also included the Soko Islands region.

In Table 2.1 an overview is given of some characteristics of the detail model.

Simulation period wet season	01/08/1992 - 15/08/1992
Simulation period dry season	06/01/1993 - 20/01/1993
Time step	60 sec
Horizontal grid dimensions	91 * 103
Number of Layers	10 layers of 10% each
Initial conditions	derived from Upgraded model
Boundary conditions salinity	generated by Upgraded model
Roughness	0.020 $s/m^{1/3}$
Horizontal eddy viscosity	1.0 m^2/s
Horizontal eddy diffusivity	1.0 m^2/s
Turbulence model	k-ε model

Table 2.1: Characteristics of detailed model

The dimensions of the new detail model are 91 by 103 grid points, of which about 7000 points are active. It should be noted that the Lamma Island grid of Stage I contained about 5600 active grid points. This new detail model for the Lamma Island region has been nested into the so-called "Upgraded model" and not into the "Pearl Estuary model", which was used for the generation of boundary conditions in Stage I of the EIA. The "Upgraded modek" was recently set up for the Hong Kong Government as a regional model of Hong Kong waters (CED, 1998) to meet more stringent standards than were applied in the past for such models. The "Upgraded model" and yields more accurate results for the area around Hong Kong Island and near the open ocean boundary in comparison to the Pearl Estuary model.

For the exchange of heat between air and water the excess temperature model of the DELFT3D-FLOW system has been applied (Delft Hydraulics, 1998a). In this model the temperature of the surface layer relaxates to a background temperature specified by the user. In the excess temperature model, the heat exchange is represented by a bulk exchange formula:

$$Q_{tot} = \lambda(t_w - t_{back})$$

This formulation is denoted as the excess temperature model. The temperature of the surface layer t_W relaxates to the natural background temperature t_{back}.

The heat exchange coefficient λ is a function of temperature t. The relation following Sweers (1976) is used:

$$\lambda = 4.48 + 0.049\, t_{sur} + f_{wind}(1.12 + 0.018\, t_{sur} + 0.00158\, t_{sur}^2)$$

For the wind function f_{wind} we have

$$f_{wind} = \left| \frac{50.10^6}{S_{area}} \right|^{0.05} (3.5 + 2.0.U_{10}) \qquad (9.3.112)$$

with

S_{area} = representative area of the model which is influenced by the wind in m^3
U_{10} = wind speead at 10 m above the sea surface

2.2 Scenarios and reclamations

In this activity thermal modelling for the existing Lamma Island Power Station is compared with two possible extensions:

- The situation with a new Power Station site (reclamation 1).
- The situation with a new Power Station site (reclamation 1) and with a proposed site for the Waste-to-Energy Incineration Facility (WEIF) (reclamation 2).

In Figure 2.1.3 the locations of the new Power Station site and the Waste-to-Energy Incineration Facility are shown. These new sites were also part of the hydrodynamic assessment in (Delft Hydraulics, 1998b).

New Power Station site

Reclamation 1 covers an area of approximately 26 ha. In the simulations this reclamation is modelled by setting grid cells permanently dry. Between the existing and the new power station there is a channel. It has been assumed that this channel is blocked, because it is not yet known whether or not this channel will be blocked. In the hydrodynamic assessment activity it was decided to model a closed situation (Delft Hydraulics, 1998c), because a blocked channel is considered to be a worst case situation. In the present study the same approach has been applied.

Waste-to-Energy Incineration Facility
Reclamation 2 covers an area of approximately 17 ha. As for the new power station reclamation this reclamation is modelled by setting grid cells permanently dry. Between reclamation 1 and reclamation 2 there is an open channel of 200 m wide, see Figure 2.1.3.

2.3 Plume rise modelling

In the present project no plume rise modelling has been carried out. Use has been made of the plume rise modelling results of Stage I of the EIA, see (Delft Hydraulics, 1997). For the sake of completeness these results are summarised below.

The plume rise modelling is only meant to let the plume rise from the diffusor to the surface. Its major emphasis is on the prediction of the plume geometry and dilution characteristics within the initial mixing zone. The heated cooling water discharged at the sites rises and mixes in the receiving water. The spreading of the thermal plume, in its region of initial mixing, is affected by the buoyancy and momentum of the discharge and is referred to as initial dilution. This is completed within a matter of minutes. It is expected that the heated cooling water discharged in the stratified sea water conditions near Lamma Island will lead to a surface floating plume. The results of the plume rise modelling are used as input for the plume dispersion modelling. The vertical positions of the discharges are determined.

In Stage I of the EIA plume rise modelling was performed with the near-field model CORMIX. CORMIX is a series of software systems for the analysis, prediction and design of, among others, pollutant discharges into diverse water systems (CORMIX, 1992). This system simulates submerged single jets, a series of submerged jets as well as buoyant surface discharges. The simulation of different jets and plumes in CORMIX is mainly based on analytical expressions with empirical coefficients. Many hydraulic scale measurements and field measurements on diffusors were considered to derive these expressions. From the user point of view the CORMIX system is more or less a black box.

For the Lamma Island power station study numerous computations were performed with CORMIX in (Delft Hydraulics, 1997). Based on the plume rise results the three layers near the surface were selected as outfall locations. However, during the thermal plume modelling phase in (Delft Hydraulics, 1997) it was observed that this choice is not very critical. Discharging into, for example, the two upper layers or into the four upper layers gave rise to more or less similar results.

In the present activity use has been made of these conclusions. Thus, the discharges to be modelled will be equally divided over the three top layers. Similar to the thermal modelling in (Delft Hydraulics, 1997), 3D models with ten equidistant layers in the vertical direction have been applied.

2.4 Thermal operation of Lamma Island power station

The main objective in this report is to investigate the effects of thermal discharges for possible extensions of the Lamma Island power station. The thermal spreading of potential sites will be simulated by using mathematical models. The goal is to compute 2°C temperature rise zones as a result of the heated cooling water discharges at existing and new outfalls. All data required for the plume dispersion modelling, such as intake and outfall locations and discharge rates, has been specified by HEC.

In this activity thermal plume modelling is conducted for three scenarios, namely the existing Lamma Island power station and the situations with an extended Lamma Island power station and with a proposed site for the Waste-to-Energy Incineration Facility, see also Chapter 2.2. The co-ordinates of the existing and new outfalls are:

- Existing outfall for units 1-6 at (828651E, 808909N).
- Existing outfall for units 7-8 at (828679E, 808991N).
- For the Lamma Island power station extension two additional outfalls at location (828690E, 808454.95N) and (828690E, 808282.95N), respectively.
- For the Waste-to-Energy Incineration Facility the outfall is situated at the mid point of the western side.

The location of the existing outfall for units 1-8 have been taken from Stage I of the EIA (Delft Hydraulics, 1997).

The existing cooling water intakes at Lamma Island power station are located at:

- For units 1-3 at location (808650N, 828983E)
- For units 4-6 at location (808650N, 829215E)
- For units 7-8 at location (808650N, 829306E)

For the Lamma Island power station extension the intakes are located north of the extension, which is close to the intakes of the existing Lamma Island Power station. For the Waste-to-Energy Incineration Facility the intake is at the mid point of the eastern side. The grid cells in this model representing the outfalls and intakes are listed in Table 2.2. In Figure 2.1.2 the outfall and intake locations are illustrated.

The height of the existing intakes is about 4.4 m and are located about 7 m below the water surface. The detailed model has ten equidistant layers in the vertical direction. Therefore, the intake values (for salinity, the conservative substance and the substance with first order decay) are computed by averaging the values in layers 5 to 10, which corresponds to a thickness of roughly 4 to 5 m. The discharge of flow and substances takes place at the three layers near the surface. The vertical distribution of the intake and outfall locations is identical to the ones in Stage I of the EIA (Delft Hydraulics, 1997b). Table 2.2 shows the locations of the intakes and outfalls in model coordinates (M represents columns and N rows).

	Outfalls	Intakes
scenario 1; Outfall 1+2	(M=52, N=58)	(M=56, N=55)
scenario 2; Outfall 3	(M=50, N=56)	(M=56, N=55)
Outfall 4	(M=48, N=55)	
scenario 3	(M=44, N=53)	(M=49, N=51)

Table 2.2: Outfall and intake locations in detail modeled

The simulations were carried out with the Delft3D-FLOW system, which is Delft Hydraulics' system for the simulation of hydrodynamic flows and conservative transport processes (Delft Hydraulics, 1998a). A dedicated recirculation model has been implemented in the Delft3D-FLOW system in order to accurately simulate the operation of the power station with the proposed discharges. Adaptation of the present discharge module in Delft3D-FLOW was required. In the Delft3D-FLOW system intakes and outfalls are independent of each other. For the present activity the implementation of intakes and outfalls was changed in order to dynamically couple the intake and outfall. In the recirculation module the intake salinity and temperature values were applied immediately at the corresponding outfall location. Also, the amount of water that is taken in is identical to the discharged amount of water. It has been assumed that there is no delay time between the intake and the outfall. This was also assumed in Stage I of the EIA, because HEC has advised that the time taken for water to pass through the cooling system is approximately 500 seconds and therefore this is a valid assumption, (Delft Hydraulics, 1997b).

The discharge rates have been based on a worst case situation for peak days in the years 2002 and 2012. For the existing situation discharge rates for a peak day in 2002 has been applied, whereas for the Lamma Power extension and the Waste-to-Energy Incineration Facility data for a peak day in 2012 has been used. All heat discharge rates have been specified by HEC.

For the outfall temperature the applied intake temperature is increased by a time dependent temperature rise, which varies for each scenario. Based on the known discharge rates and heat rejections for each scenario the temperature rise can be computed for each hour at the peak day. Since the discharge rates and heat rejections vary for each scenario and are also different for the wet and dry season situations, for each simulation a table with temperature rises is given in the next chapters. In these chapters the wet and dry season simulations will be described.

2.5 Model output

For all scenarios maximal temperatures contours are shown for a neap tide period and a spring tide period during both a wet and a dry season. For the wet season the neap tide period of 1-7 August 1992 and the spring tide period of 8-14 August 1992 have been chosen. Similarly, for the dry season the spring tide period of 6-12 January 1993 and the neap tide period 13-19 January 1993 has been used. These periods are identical to the ones applied in the hydrodynamic assessment (Delft Hydraulics, 1998c). In Stage I of the EIA simulation periods of six days were considered. By using a total simulation period of fourteen days the simulations are now closer to the length of a full spring-neap cycle, which corresponds to a period of approximately 14.5 days.

Sensitive receivers
A time series of temperature will be given at the following sensitive receivers (locations of these stations can be found in Figure 2.1.2):

- at power station outfall location (varies per scenario)
- at Lamma Island power station intake
- at Hung Shing Ye Beach
- at Lo So Shing Beach
- at South Lamma Marine Park 1
- at South Lamma Marine Park 2
- at Shek Kok Tsui Coral
- at Pak Kok Coral

In all scenarios there is hardly any temperature rise at the bottom layers. Therefore, only results for the four layers near the free surface (layers 1 to 4) are presented. Layer 1 represents the surface layer. The maximal temperature contours represent the maximal temperature at the grid points during the whole simulation period (neap tide period of seven days and a spring tide period of seven days).

3 Wet season simulations

The wet season simulations were performed for the period of 1 August 1992 to 15 August 1992. Results are shown for 1-8 August 1992 (neap tide period) and for 8-15 August 1992, which represents a spring period. A 'warm up' period of four days (from July the 28th 0:00 hrs to 1 August 0:00 hrs) has been used, before the 'real' simulations start. This was, however, not necessary, because the model results are already adapted to the external forcings (Delft Hydraulics, 1998b). The results of the spin-up period were not taken into account in the thermal modelling.

In the wet season simulations a uniform temperature of 28°C was used as the initial condition, which is identical to the temperature used in Stage I of the EIA (Delft Hydraulics, 1997). Thus, both at 1 August (start of neap period) and at 8 August (start of spring period) there is a uniform initial temperature of 28°C. This can clearly be seen in the time history plots of temperature in e.g. Figures 3.1.3-10. A uniform initial value has been prescribed, because not much temperature data (horizontal and vertical distribution) for the region around Lamma Island was available. For the exchange of heat between air and water the excess temperature model of the DELFT3D-FLOW system has been applied (Delft Hydraulics, 1998a). In this model the temperature of the surface layer relaxates to a background temperature specified by the user. A background temperature of 28°C has been applied.

The aim is to compute the 2°C temperature rise zone. This involves all grid points for which the *maximal* temperature at any time during the whole simulation period is more than 2°C higher than the background temperature. In the figures the maximal temperatures from 28°C to 37°C with an interval of 1°C are presented. Thus, not only the 2°C rise, but also the other temperature rise zones for the other whole numbers are shown, see also Section 3.4.

3.1 Scenario 1: existing Lamma Power station

The initial thermal simulations were for the existing Lamma Island power station. In Table 3.1 the discharge rates, heat rejections and temperature rise are given. Figure 3.1.1 contains the maximal temperature contours for the neap tide period of 1-8 August 1992, whereas in Figure 3.1.2 the maximal temperature contours for the spring tide period of 8-15 August 1992 are presented. For the four top layers temperature contours are shown. In Figures 3.1.3-10 time histories of temperature are given for the locations specified in Chapter 2.5.

Although the surface temperatures at the outfall reach values up to 34°C, the heated zone is limited due to tidal velocities and heat exchange with the atmosphere. For this scenario the 2°C temperature rise zone is 7.6 km^2 for the neap period and 10.1 km^2 for the spring period.

Although it is very difficult to compare these results with the temperature rise zones computed for the existing situation in Stage I of the EIA (Delft Hydraulics, 1997), the thermal plumes are roughly in agreement with each other. The heat rejection applied in Stage II is roughly twice as large as the one in Stage I, cf. Table 5.6 in (Delft Hydraulics, 1997). The 2°C temperature rise zones computed in the present project are also about twice as large (7.6 km^2 and 10.1 km^2 versus 3 km^2 and 6 km^2, respectively). However, the location of the plumes is comparable, namely roughly southwest of the outfall location. Both in Stages I and II the temperature rise zone for the spring period is larger than the one for the neap tide period.

Since the discharge rates and the heat rejections, especially during the day, are very different at both stages, the conclusions should be considered in a very careful way. For example, in Stage I the heat rejection during the first eight hours was almost neglectable, whereas in Stage II there is already a considerable heat rejection at these hours. This comparison has been made in order to globally compare the results.

Existing situation (scenario 1); Wet season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0	1746.6	77.2	6.3
1	1536.2	77.2	5.5
2	1444.2	77.2	5.2
3	1394.5	77.2	5.0
4	1358.9	77.2	4.9
5	1347.4	77.2	4.8
6	1371.9	77.2	4.9
7	1592.0	77.2	5.7
8	2075.4	87.6	6.6
9	2417.9	98.0	6.9
10	2517.4	98.0	7.1
11	2590.7	98.0	7.3
12	2590.7	98.0	7.3
13	2590.7	98.0	7.3
14	2590.7	98.0	7.3
15	2590.7	98.0	7.3
16	2590.7	98.0	7.3
17	2590.7	98.0	7.3
18	2506.6	98.0	7.1
19	2468.3	98.0	7.0
20	2389.8	98.0	6.8
21	2350.1	98.0	6.7
22	2168.8	87.6	6.9
23	2000.9	87.6	6.3
average	2117.6	89.7	

Table 3.1: Heat rejection and discharge rates for existing situation

The time histories in Figures 3.1.3-10 show that at the intake temperature values of up to 30°C are reached in the whole water column. During neap the temperatures at Hung Shing Ye Beach, Lo So Shing Beach, South Lamma Marine Park 1 and 2 and at Pak Kok Coral do not increase with more than 1°C. During spring the thermal plume reaches the south-western coast, which is not the case for the neap period, and consequently the temperatures at the locations of interest in that region are somewhat higher for the spring period.

3.2 Scenario 2: Lamma Power station extension

Scenario 2 represents the situation with an extension of the Lamma Island power station located south of the existing power station, see reclamation 1 in Figure 2.1.3. The discharge rates and heat rejections for this scenario are specified in Table 3.2. It should be noted that in this table the total values are given, representing the sum of the values for the existing power station and its extension. It should be noted that the daily averaged values are almost comparable with the ones for the existing situation, see the last row in Tables 3.1-2. This means that for the extension of the Lamma Island power station less water is discharged compared to scenario 1. This difference is more or less comparable to the amount of discharged water for the power station extension.

For scenario 2 the heat rejection during the first eight hours is much less and during the hours 10-18 higher compared to scenario 1. So, the main difference between these two scenarios is the spreading over the day.

Lamma Power Station extension (scenario 2); Wet season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0	1440.3	58.8	6.8
1	1161.4	58.8	5.5
2	1098.2	58.8	5.2
3	1065.5	58.8	5.0
4	1043.8	58.8	4.9
5	1036.7	58.8	4.9
6	1051.2	58.8	5.0
7	1230.9	58.8	5.8
8	1941.2	86.2	6.3
9	2467.6	99.8	6.9
10	2858.2	120.6	6.6
11	2963.7	120.6	6.8
12	3056.3	120.6	7.0
13	2979.2	120.6	6.9
14	2985.6	120.6	6.9
15	3004.3	120.6	6.9
16	2969.1	120.6	6.8
17	2955.2	120.6	6.8
18	2844.3	120.6	6.6
19	2650.3	110.2	6.7
20	2430.2	99.8	6.8
21	2285.3	99.8	6.4
22	2068.6	86.2	6.7
23	1796.3	72.5	6.9
average	2141.0	92.1	

Table 3.2: Heat rejection and discharge rates for power station extension

Despite the fact that the heat rejection is comparable to scenario 1, the temperature rise zones are smaller. For example, the 2°C temperature rise zone is 5.7 km^2 for the neap period and 7.8 km^2 for the spring period, which is roughly 25% less compared to the model results for the existing situation. This is caused by the different discharge regime in combination with the tidal behaviour.

The time history of temperature for the intake (Figure 3.2.4) shows that the temperature at the intake hardly increases due to the heat rejection for the existing and the new power station. In order to reach the intake location the heated discharged water has "to travel around" the reclamation for the new power station.

3.3 Waste-to-Energy Incineration Facility

Scenario 3 is devoted to the simulation of an additional reclamation, representing the Waste-to-Energy Incineration Facility (WEIF). For the WEIF a rather simple discharge regime is applied. It has been assumed that the discharge rate and temperature rise are constant during the whole day, see Table 3.3. We remark that Table 3.3 only contains the values for the WEIF, which is different form Table 3.2. In Table 3.2 the sum of the values for the existing and power station extension are shown. In the simulations for the WEIF we use the heat rejections (and discharge rates) of Table 3.2 increased by the values in Table 3.3. As a result, for the daily average discharge rate we arrive at 92.1+14.8=106.9 m^3/s.

Waste-to-Energy facility (scenario 3); Dry season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0-23	319.7	14.8	6.0
average	2460.7	106.9	

Table 3.3: Heat rejection and discharge rates for WEIF

Owing to the additional discharge for the WEIF the temperature rise zone is larger compared to scenario 2. The size of the 2°C temperature rise zone is more or less comparable to one for scenario 1. Although the size is comparable to the existing situation, the location of the plumes are somewhat different. For the WEIF scenario the plume is more in southern direction, whereas for the existing situation the dispersion of the plume is more in westerly direction.

For all three scenarios the heated discharge water hardly reaches the area near Hung Shing Ye and near Lo So Shing.

3.4 Overview of temperature rise zones

This chapter is concluded with an overview of temperature rise zones. In the previous sections the areas for a 2°C temperature rise have been given. The areas for other values of the temperature rise are now specified as well. The temperature rise zone is defined as the area in which the *maximal* temperature in *one or more* vertical layers during the whole simulation is several degrees higher than the background temperature.

Scenario	Tide	1°C rise (km^2)	2°C rise (km^2)	3°C rise (km^2)	4°C rise (km^2)
Scenario 1	Neap	22.7	7.6	2.5	1.0
Scenario 1	Spring	31.1	10.1	3.1	1.3
Scenario 2	Neap	16.4	5.7	2.2	0.3
Scenario 2	Spring	24.1	7.8	3.1	1.3
Scenario 3	Neap	19.6	7.6	2.8	1.3
Scenario 3	Spring	34.1	10.2	3.6	1.4

Table 3.4: Overview of temperature rise zones for wet season simulations

4 Dry season simulations

The dry season simulation period is from 6 January to 20 January 1993. This period covers both a spring (6-12 January 1993) and a neap period (13-19 January 1993). The simulation period is divided into two periods. Numerical results are shown for 6-12 January 1993 (spring) and 13-19 January 1993 (neap). Similarly to the wet season simulation, the results for the spin up period of 1 to 6 January 1993 are not used.

In the dry season simulations an initial uniform temperature of 17°C is used in both the horizontal and vertical directions, which is identical to the temperature used in Stage I of the EIA (Delft Hydraulics, 1997). A background temperature of 17°C has been used.

Existing situation (scenario 1) ; Dry season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0	1006.1	53.2	5.3
1	917.5	53.2	4.8
2	857.6	53.2	4.5
3	819.2	53.2	4.3
4	802.7	53.2	4.2
5	803.8	53.2	4.2
6	863.0	53.2	4.5
7	1100.6	53.2	5.8
8	1567.0	66.8	6.5
9	1904.7	77.2	6.9
10	2162.3	87.6	6.9
11	2147.4	87.6	6.8
12	2203.6	87.6	7.0
13	2153.7	87.6	6.8
14	2180.5	87.6	6.9
15	2119.0	87.6	6.7
16	2082.1	87.6	6.6
17	2086.5	87.6	6.6
18	2082.7	87.6	6.6
19	1880.9	77.2	6.8
20	1616.3	66.8	6.7
21	1501.3	66.8	6.2
22	1374.9	66.8	5.7
23	1189.2	53.2	6.2
average	1559.3	70.4	

Table 4.1: Heat rejection and discharge rates for existing situation

4.1 Scenario 1: existing Lamma Power station

In Table 4.1 the discharge rates, heat rejections and temperature rise are given for the existing Lamma Island power station for the dry season period. Figure 4.1.1 contains the maximal temperature contours for the spring tide period of 6-12 January 1993, whereas in

Figure 3.1.2 the maximal temperature contours for the neap tide period of 13-19 January 1993are presented. In Figures 4.1.3-10 time histories of temperature are given for the sensitive receivers.

In comparison to the wet season simulation in Chapter 3.1, the spreading of heated water at the two top layers is larger for the dry season. In the dry season contours plots there is hardly an increase of temperature at the other eight layers. The fact that the heated water is mainly located at the two top layers is in line with the dry season results of Stage I of the EIA (Delft Hydraulics, 1997).

The maximal temperature rise zones for the neap period are more or less similar to the spring tide results. The size of the 2°C temperature rise zone (for neap and spring period) is roughly comparable for the wet and dry season (7.6 km^2 and 10.1 km^2 versus 10.2 km^2 and 9.5 km^2, respectively).

For the location of interest (see Figures 4.1.3-10) there is hardly an increase in temperature. The thermal plume hardly reaches these locations.

Lamma Power Station extension (scenario 2); Dry season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0	639.4	27.5	6.5
1	584.8	27.5	5.9
2	551.6	27.5	5.6
3	531.5	27.5	5.4
4	523.1	27.5	5.3
5	523.8	27.5	5.3
6	554.3	27.5	5.6
7	719.9	33.0	6.1
8	1231.7	58.8	5.8
9	1699.4	72.5	6.5
10	2021.8	86.2	6.5
11	2090.7	86.2	6.7
12	2162.2	86.2	7.0
13	2099.8	86.2	6.8
14	2047.2	86.2	6.6
15	1961.8	86.2	6.3
16	1911.6	86.2	6.2
17	1917.8	86.2	6.2
18	1913.4	86.2	6.2
19	1666.1	72.5	6.4
20	1298.8	58.8	6.1
21	1154.5	58.8	5.5
22	970.7	45.9	5.9
23	775.5	33.0	6.5
average	1314.6	58.4	

Table 4.2: Heat rejection and discharge rates for power station extension

4.2 Scenario 2: Lamma Power station extension

Scenario 2 is devoted to the situation with an extension of the Lamma Island power station located south of the existing power station, see reclamation 1 in Figure 2.1.3. The discharge rates and heat rejections for this scenario are specified in Table 4.2. Similarly to Table 3.2, in Table 4.2 the total values are given, representing the sum of the values for the existing power station and its extension.

The heat rejection and discharges for this scenario are roughly 20% lower than the ones for the existing situation. From the maximal temperature plots it can be seen that scenario 2 leads to smaller plumes than scenario 1. The shape of the plume is more or less comparable. However, its size is smaller because of a lower discharge rate. Similarly to scenario 1, the plume is mainly located at the two top layers.

Similarly to scenario 2 for the wet season, the intake temperatures are lower than the ones for the existing situation. Owing to the reclamation the intake is more or less hidden from the outfall locations. Therefore, the discharged water hardly reaches the intake location. At all other locations of interest there is hardly an increase in temperature, see Figures 4.2.4-10. These temperatures do not exceed 18°C, which corresponds to 1°C temperature rise.

4.3 Waste-to-Energy Incineration Facility

For the Waste-to-Energy Incineration Facility (WEIF) dry season scenario the same simple discharge regime was applied as for the wet season. It has been assumed that the discharge rate and temperature rise are constant during the whole day, see Table 4.3. It should be noted that Table 4.3 only contains the values for the WEIF, which is different form Table 3.1-2. In the simulations for the WEIF we use the heat rejections (and discharge rates) of Table 4.2 increased by the values in Table 3.3. For example, the average discharge rate is 58.4+14.8=73.2 m^3/s.

Waste-to-Energy facility (scenario 3) ; Dry season			
Hour	Heat Rejection (Gcal/hour)	Discharge rate (m^3/s)	Temperature rise (°C)
0-23	319.7	14.8	6.0
average	1634.3	73.2	

Table 4.3: Heat rejection and discharge rates for WEIF

As described above, scenario 3 represents the discharge regime of scenario 2 increased by a fixed discharge rate and temperature rise, as indicated in Table 4.3. It is therefore surprising that the temperature rise zone is smaller for scenario 3 than for scenario 2. For scenario 2 the size of the 2°C temperature rise zone (for spring and neap period) is 5.1 km^2 and 5.5 km^2 respectively, whereas we have 3.9 km^2 and 4.7 km^2 for scenario 3. The explanation might be the presence of the Waste-to-Energy Incineration Facility reclamation, which has some effect on the flows and consequently also on the thermal plume. We remark that for the wet season situation scenario 3 gave rise to a larger temperature rise zone than the one for scenario 2, see Chapter 3.3.

The time histories of temperature in the stations of interest are in line with the one of scenario 2. The temperature hardly increases (less than 1°C).

4.4 Overview of temperature rise zones

Similarly to the wet season scenarios, for the dry season an overview of temperature rise zones for not only a 2°C temperature rise is given as well.

Scenario	Tide	1 °C rise (km^2)	2 °C rise (km^2)	3 °C rise (km^2)	4 °C rise (km^2)
Scenario 1	Spring	28.1	9.5	3.1	0.6
Scenario 1	Neap	30.1	10.2	3.1	0.7
Scenario 2	Spring	20.8	5.1	1.1	0.2
Scenario 2	Neap	23.0	5.5	1.2	0.2
Scenario 3	Spring	19.1	3.9	0.6	0.4
Scenario 3	Neap	23.5	4.7	0.8	0.4

Table 4.4: Overview of temperature rise zones for dry season simulations

5 Conclusions

In this report the thermal modelling for the Lamma Island power station and potential extensions has been conducted. The principal objective is to accurately predict by means of mathematical modelling the effects of thermal discharges for the potential sites.

The same thermal plume modelling methodology has been applied as in Stage I of the EIA (Delft Hydraulics, 1997). The dispersion modelling carried out in the present project has yielded more detailed information than in Stage I, because of a higher model resolution. The new detailed model has been developed specifically for the area near Lamma Island.

Three scenarios have been examined:

1. The existing situation, describing the Lamma Island power station.
2. The situation with a new (extended) Lamma Island power station.
3. The situation with a new power station site and with a proposed site for the Waste-to-Energy Incineration Facility (WEIF).

The scenarios have been based on a worst case situation for the year 2002 or 2012. For the existing situation discharge rates for a peak day in 2002 have been applied, whereas for the Lamma Power extension and the Waste-to-Energy Incineration Facility a peak day in 2012 has been used. The size of the thermal spreading has been determined and the way in which the plume has been transported by the currents. For all scenarios the 2°C (and other) temperature rise zones for both a neap tide and a spring tide period have been computed.

The simulations representing extension of the existing Lamma Island power station and the operation of the WEIF (scenarios 2 and 3 respectively) have yielded smaller temperature rise zones than the ones for the existing situation. This holds for both the wet season and the dry season situation. This is due to the fact that for each scenario a different discharge regime has been applied. For scenarios 2 and 3 the amount of discharged water is less compared to scenario 1. Consequently, the thermal plumes for these scenarios are smaller.

For the dry season the size of the temperature rise zones for the neap and spring tide period are similar to each other. For the wet season situation the spring tide period has yielded larger temperature rise zones compared to the neap period. Between the wet and dry season situations differences can be found as well. For the dry season the heated water is mainly located in the two top layers, whereas for the wet season there is more spreading in the vertical direction.

In order to identify potential effects on sensitive receivers time histories of temperature have been generated for several of these locations.

6 References

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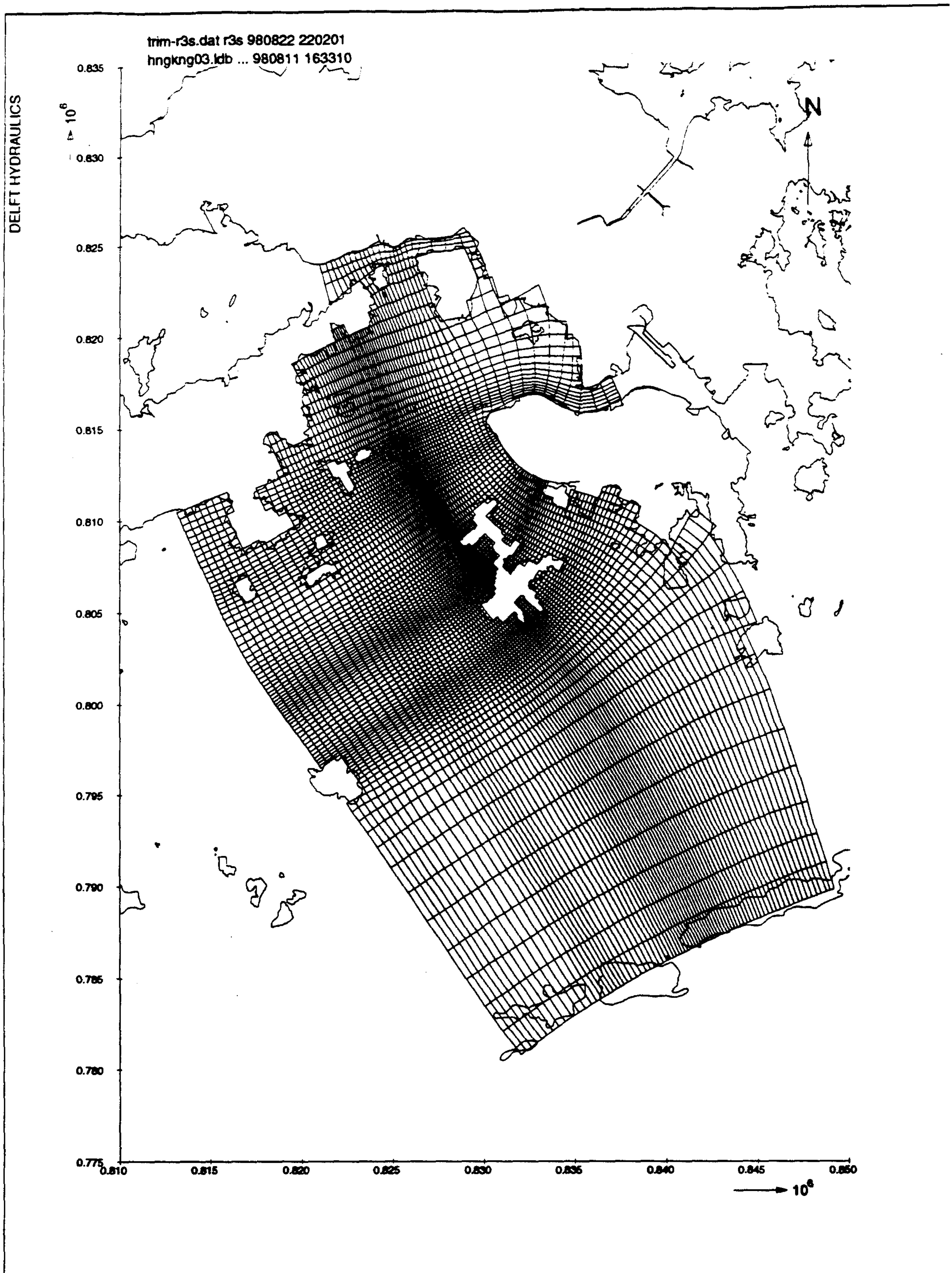

Detail model Lamma Island Grid		1998-08-28 08:48:41
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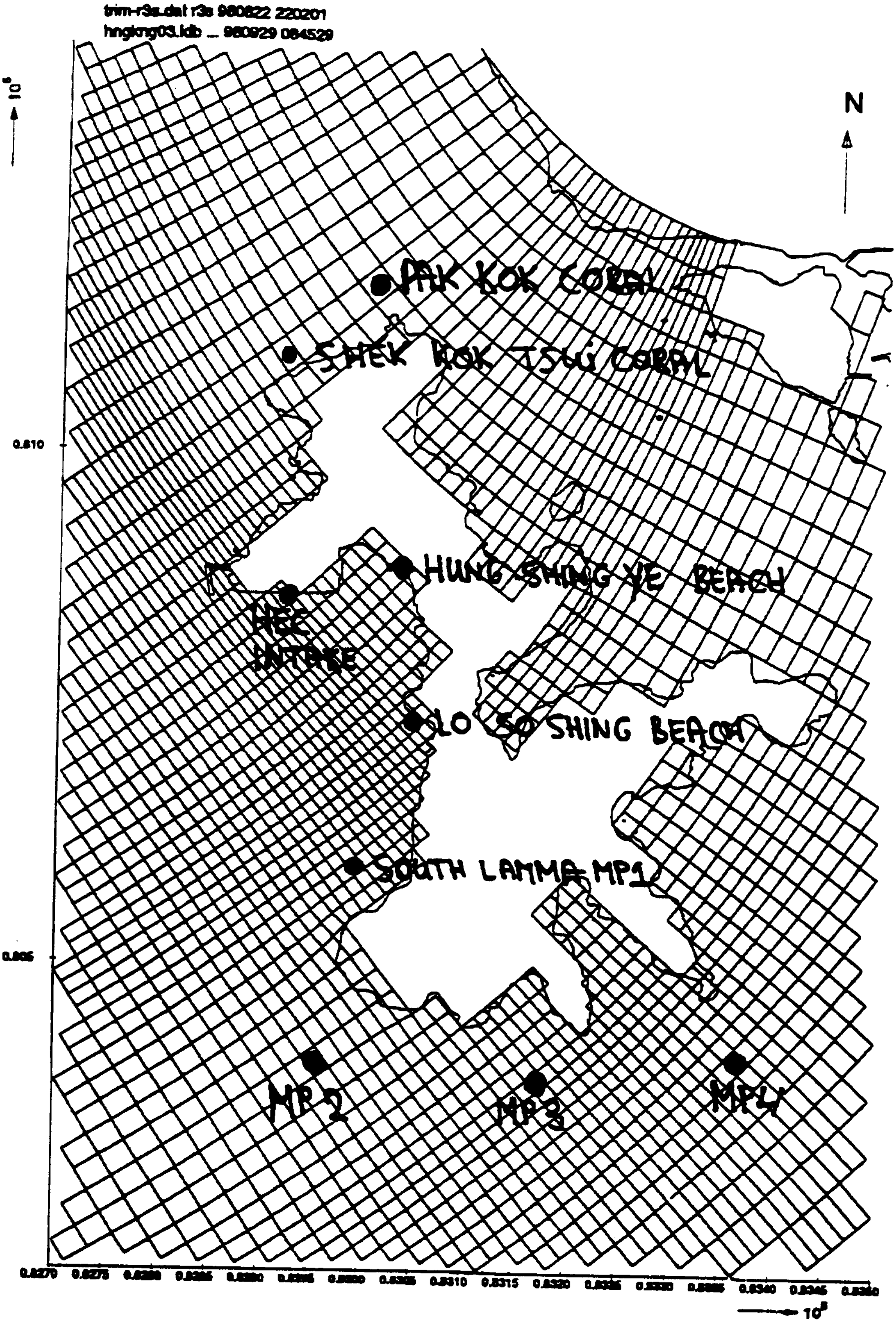
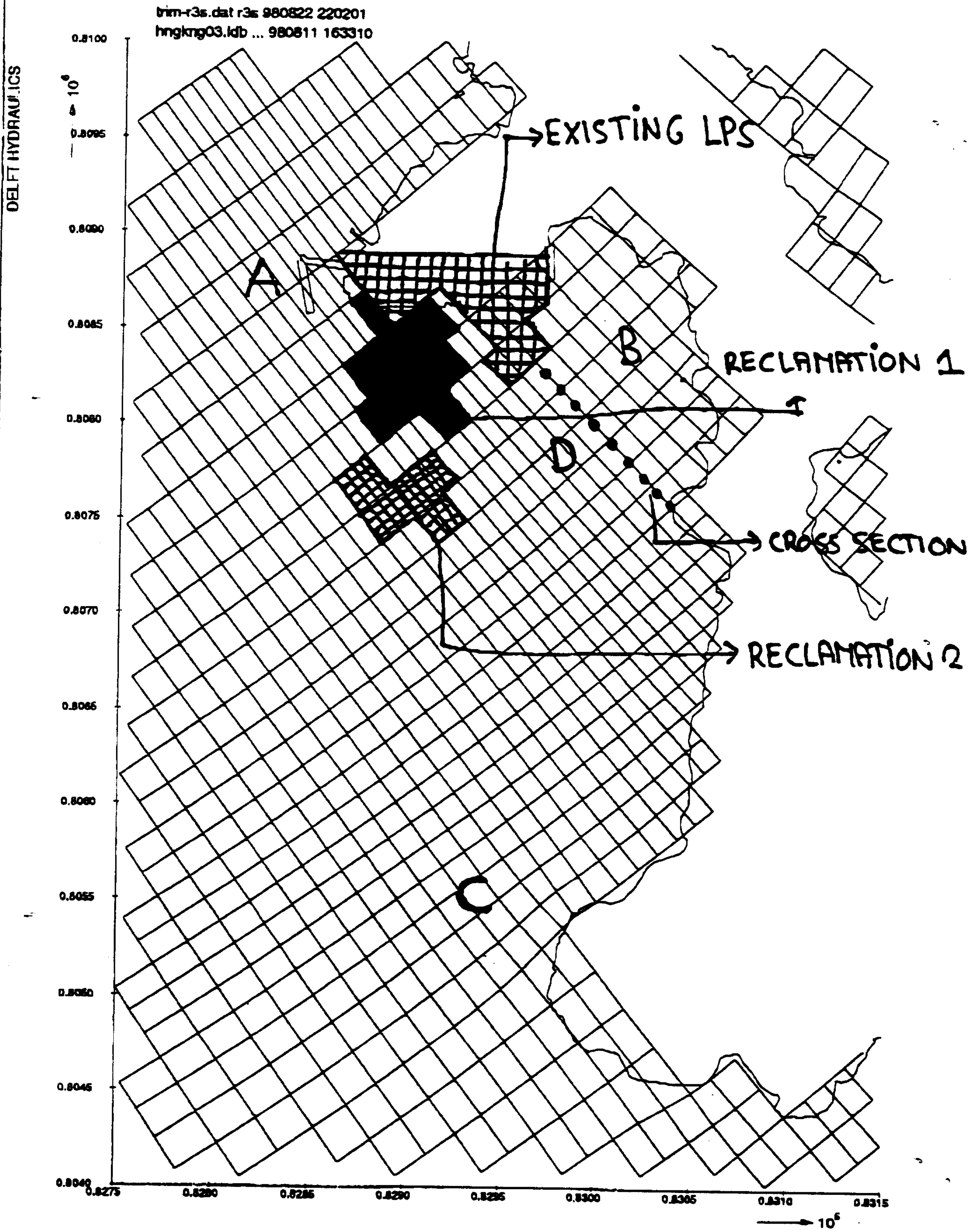
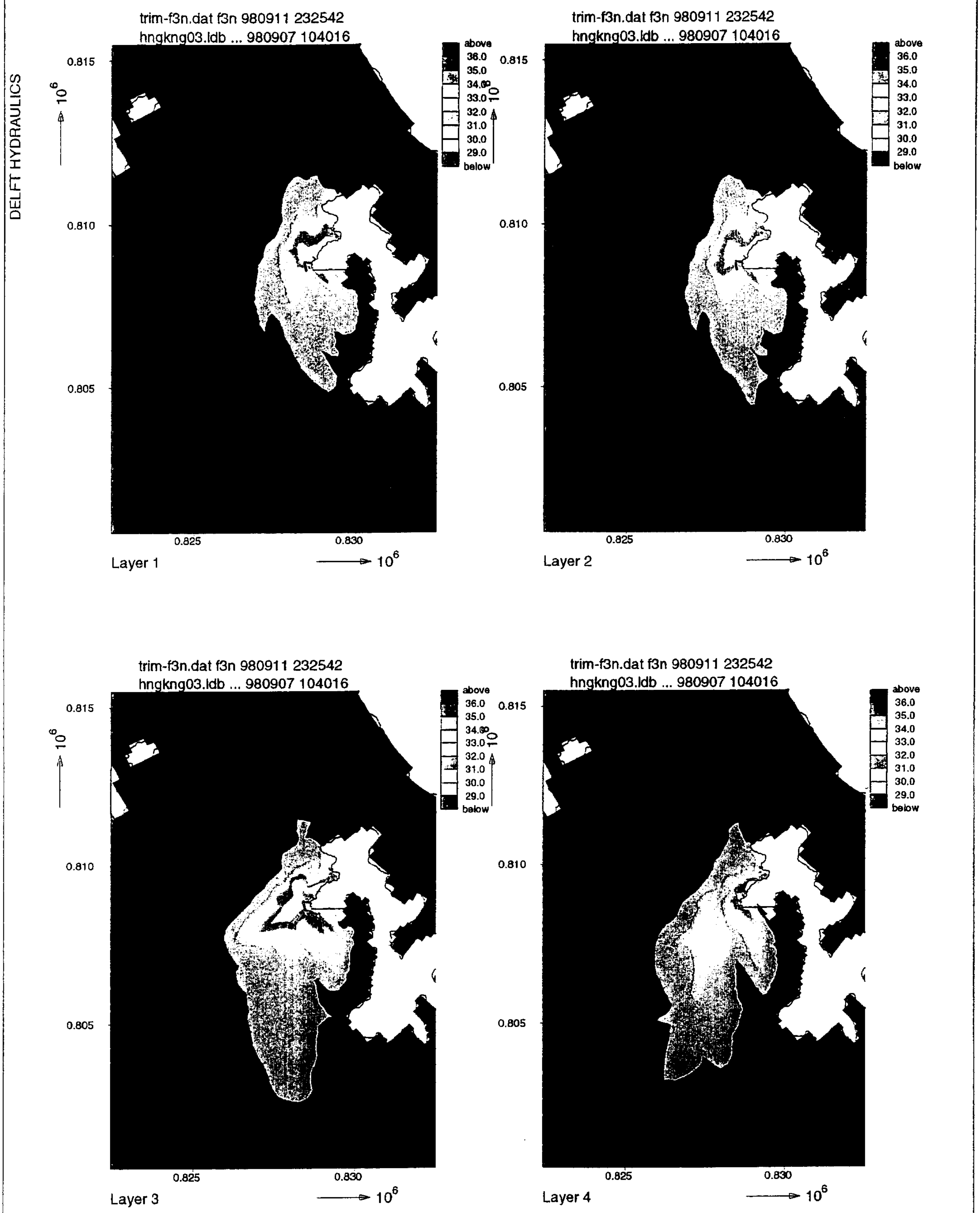
DELFT HYDRAULICS



Detail model Lamma Island Location of stations		1998-10-06 13:05:47
DELFT HYDRAULICS		Fig. 2.1.2



Detail model Lamma Island Detailed view near Power Station location	1998-08-28 08:48:42
DELFT HYDRAULICS	Fig. 2.1.3

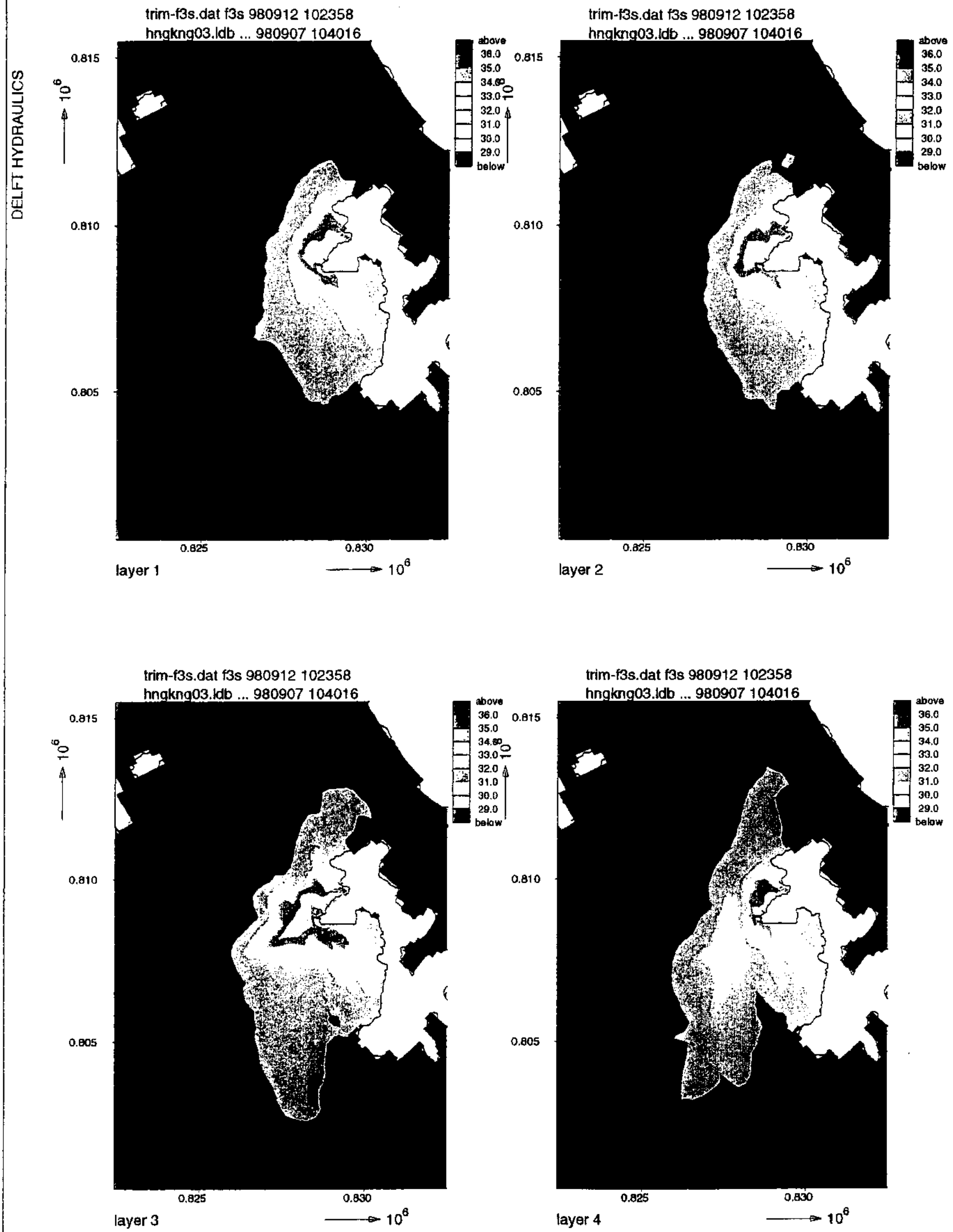


Existing Lamma Island Power Station; Scenario 1
Maximum temperature for 1-7 August 1992 (Neap tide)
Wet Season; For layers 1 to 4 (layer 1 = surface layer)

1998-09-23
13:57:17

DELFT HYDRAULICS

Fig. 3.1.1



Existing Lamma Island Power Station; Scenario 1 Maximum temperature for 8-14 August 1992 (Spring tide) Wet Season; For layers 1 to 4 (layer 1 = surface layer)		1998-09-23 13:57:22
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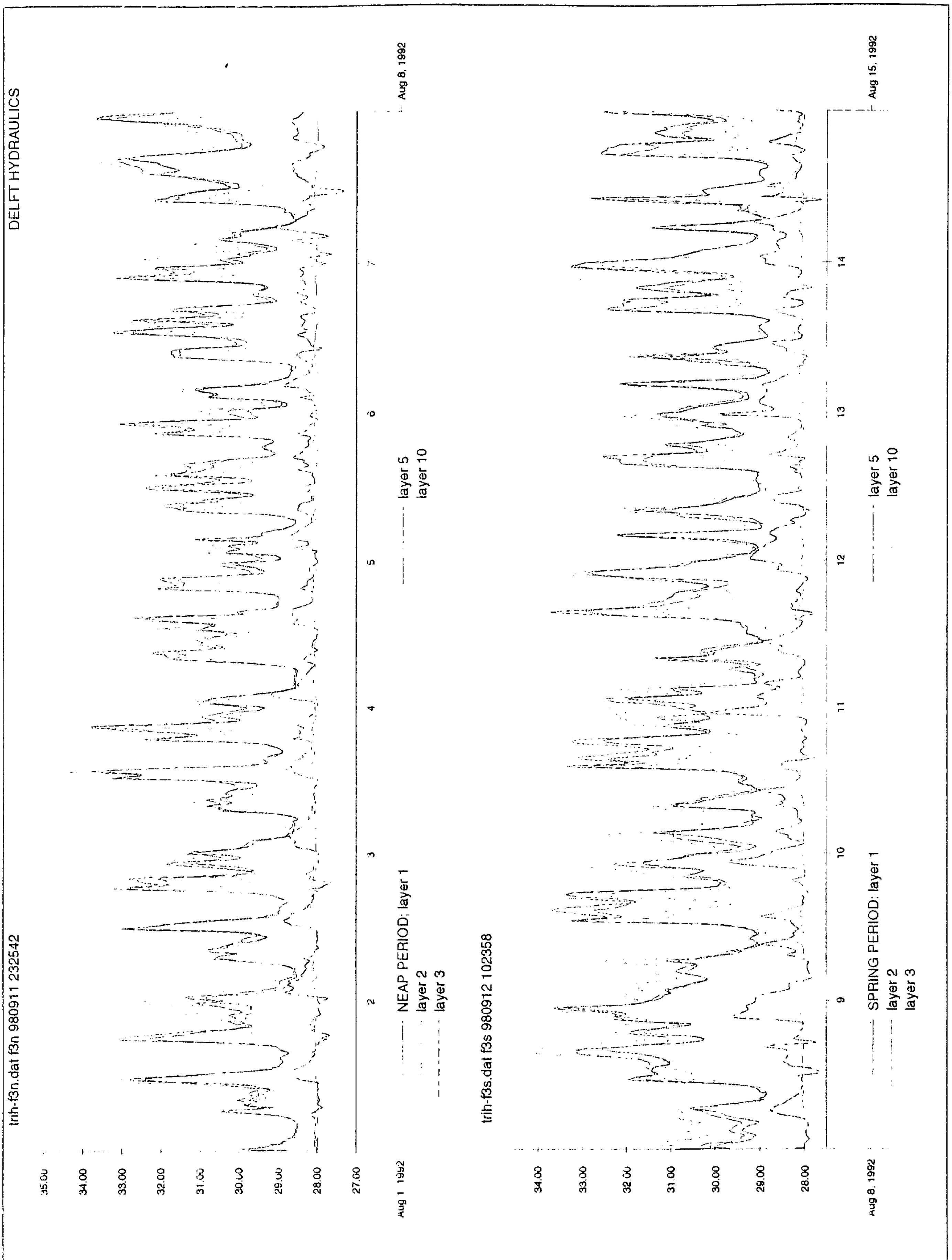

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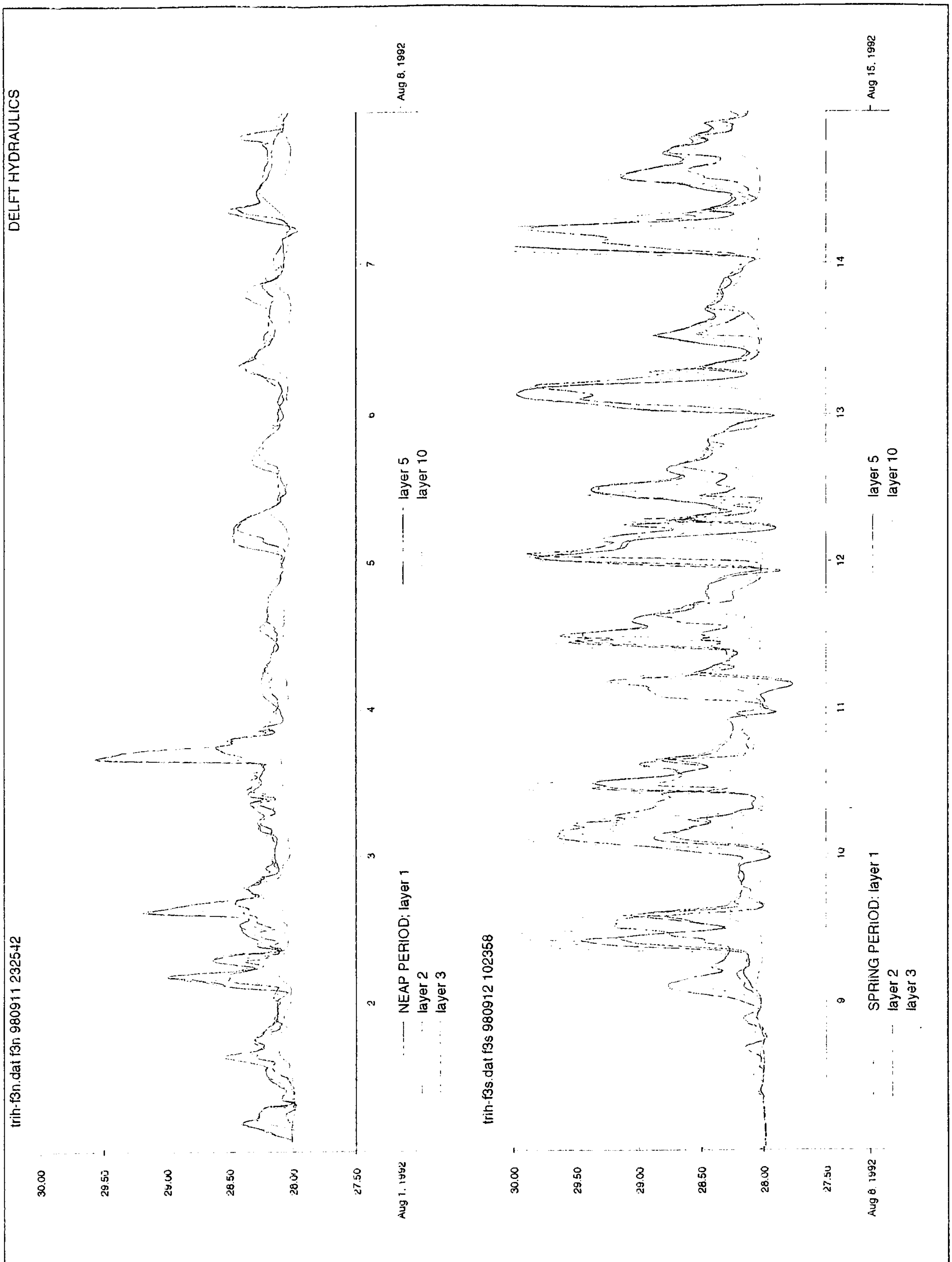

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Time series of temperature for 1-14 August 1992 (Wet season)
Lamma island Power Intake

1998-09-23
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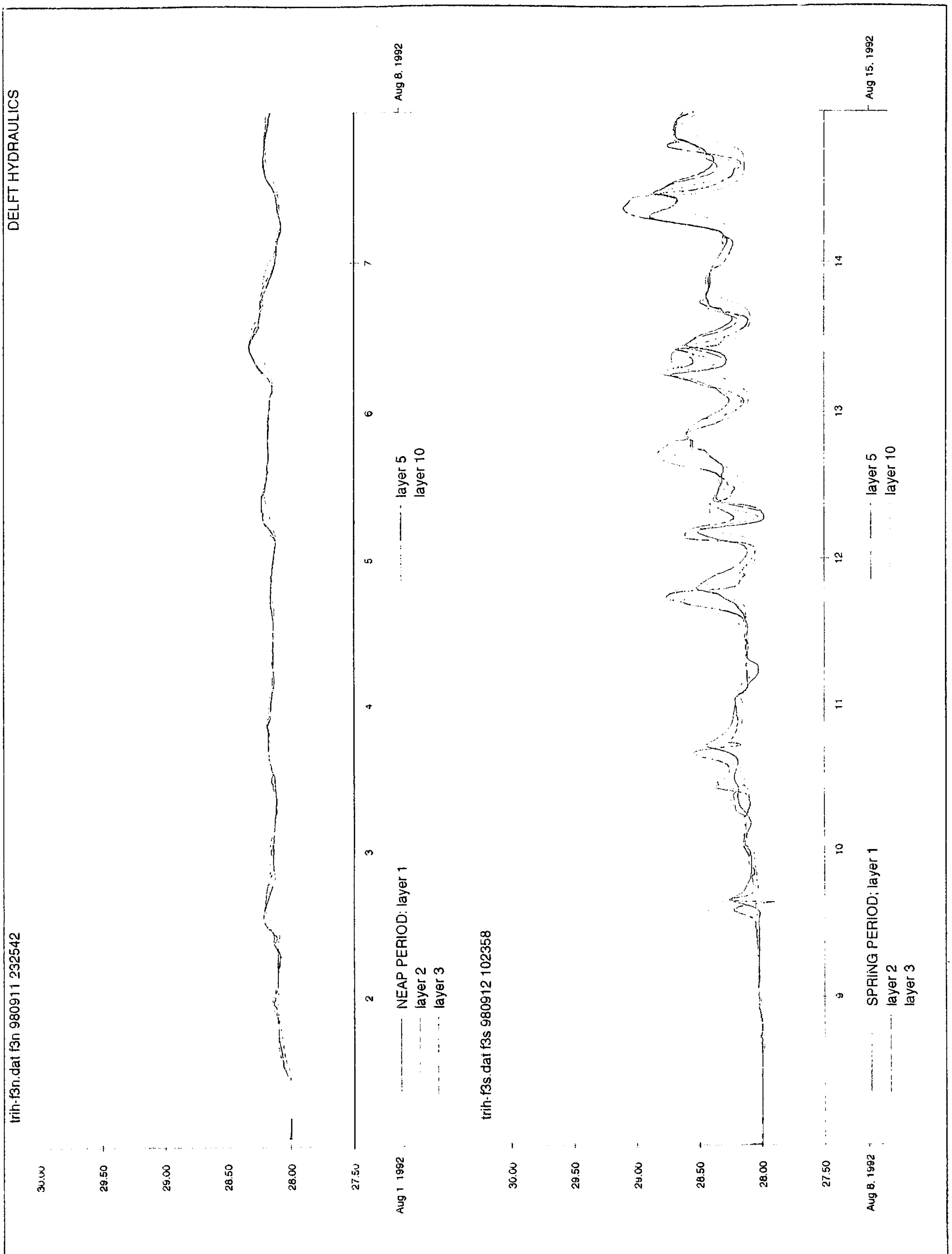
DELFT HYDRAULICS

Fig. 3.1.4



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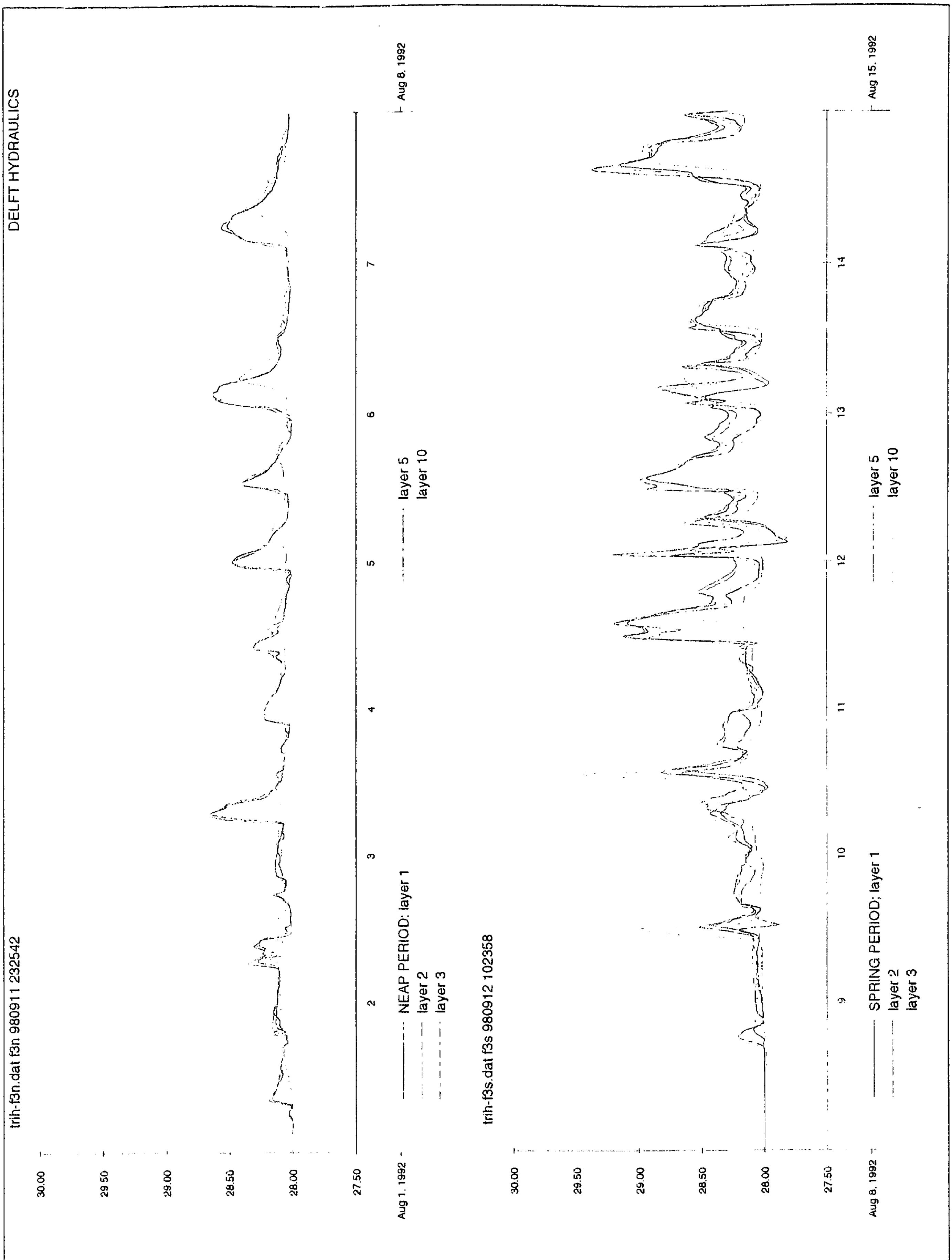

Existing Lamma Island Power Station; Scenario 1
Time series of temperature for 1-14 August 1992 (Wet season)
Lo So Shing Beach

1998-09-23
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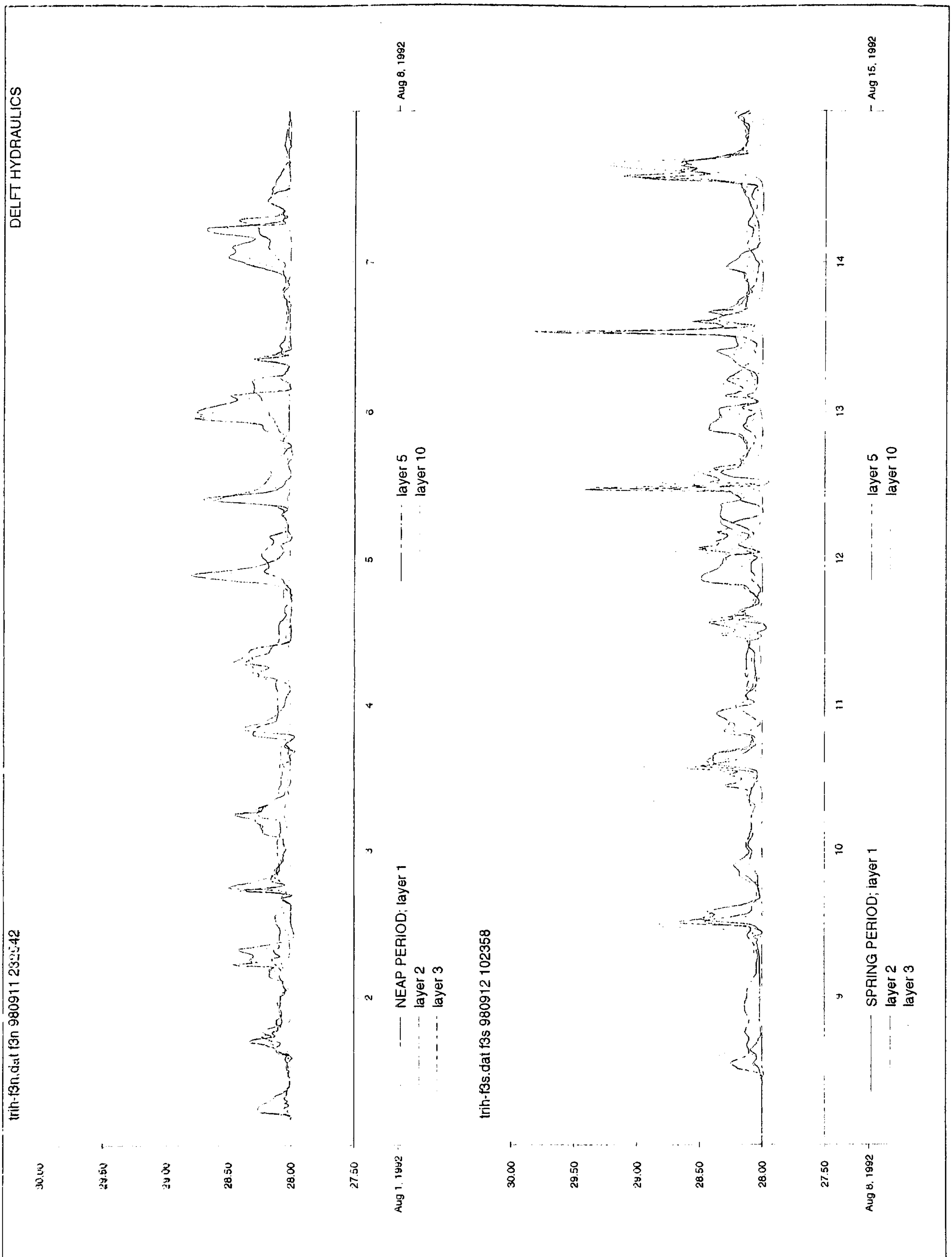
Fig. 3.1.6



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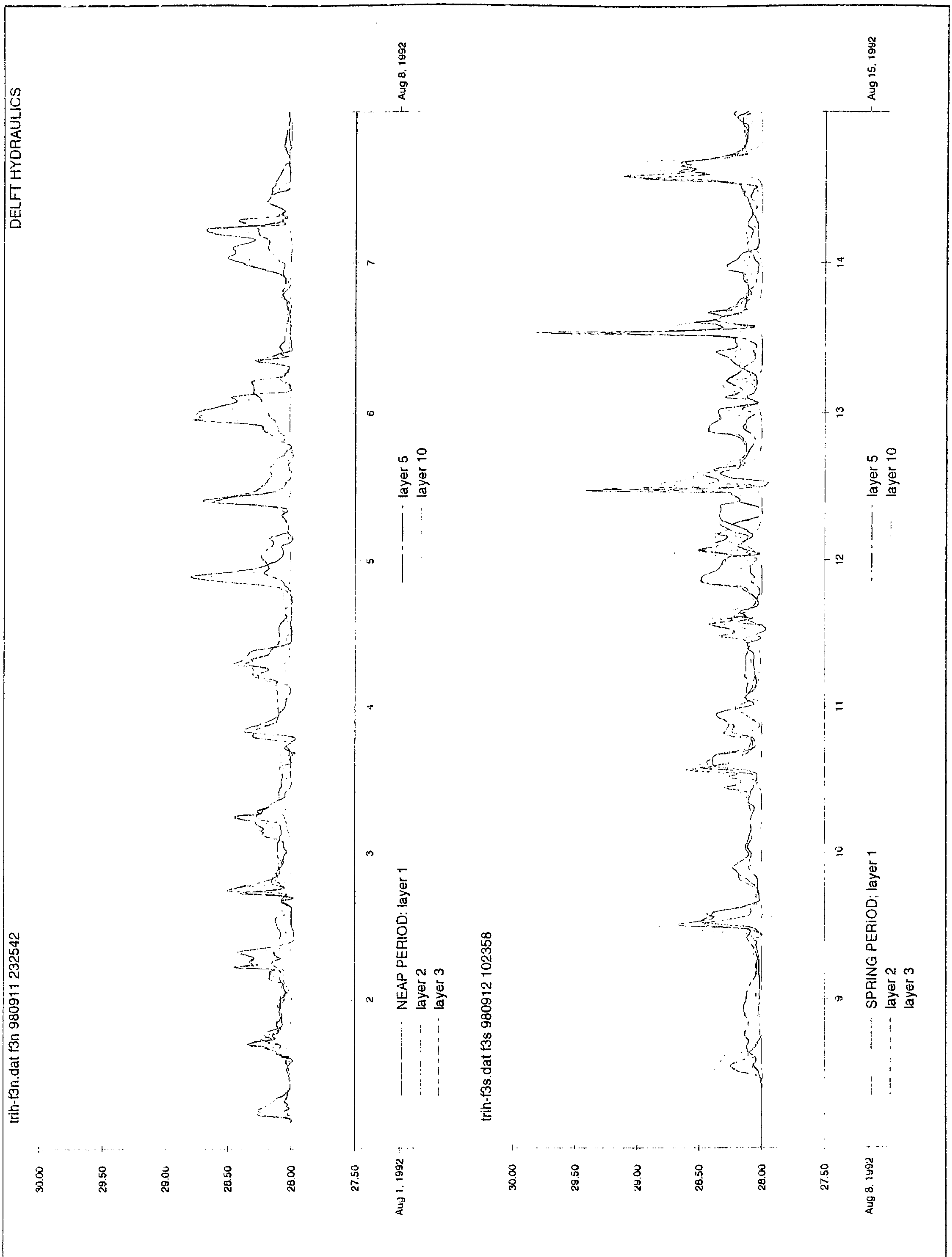

Existing Lamma Island Power Station; Scenario 1
Time series of temperature for 1-14 August 1992 (Wet season)
South Lamma Marine Park 2

1998-09-23
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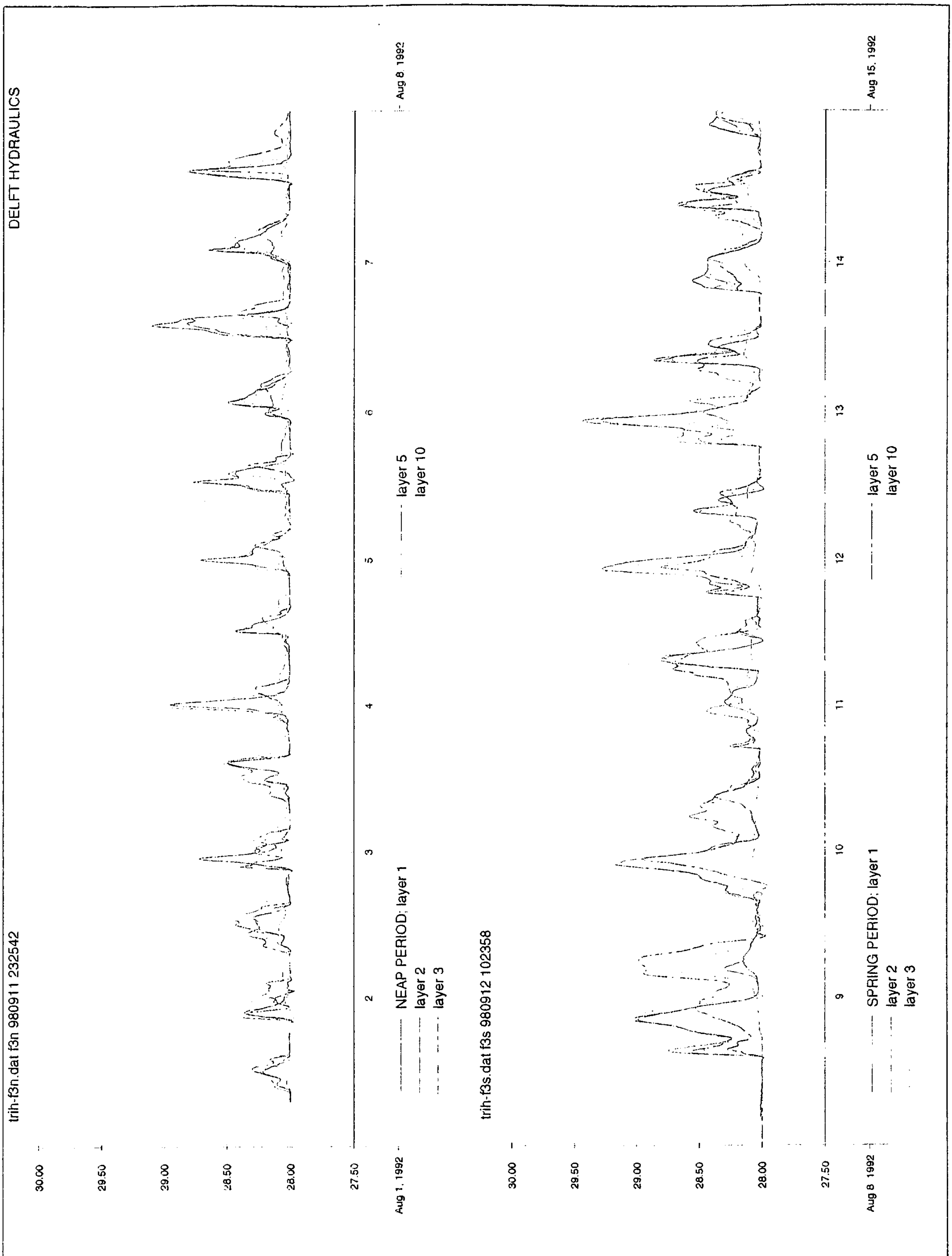
DELFT HYDRAULICS

Fig. 3.1.8



Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 1-14 August 1992 (Wet season) Shek Kok Tsui Coral		1998-09-23 15:15:24
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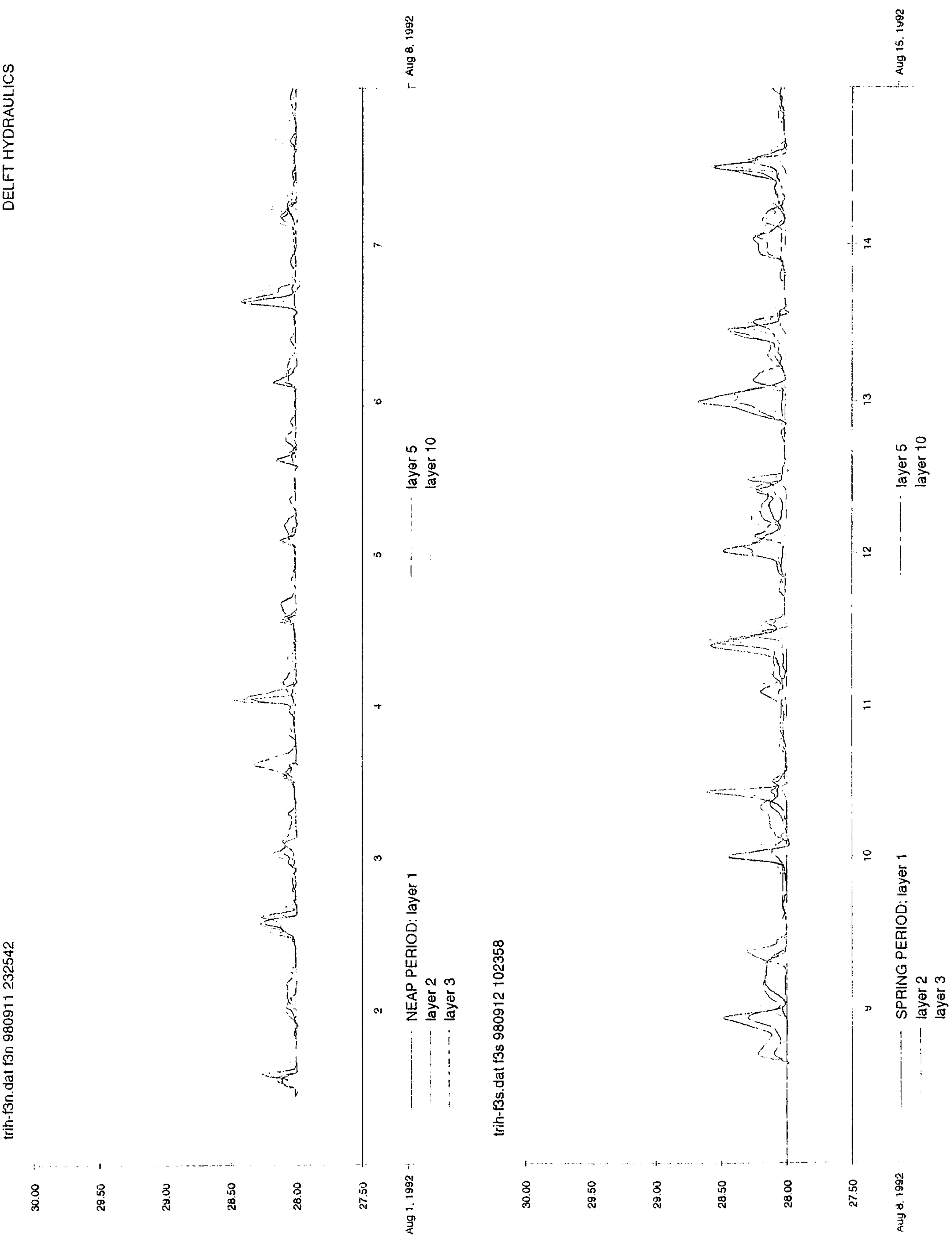


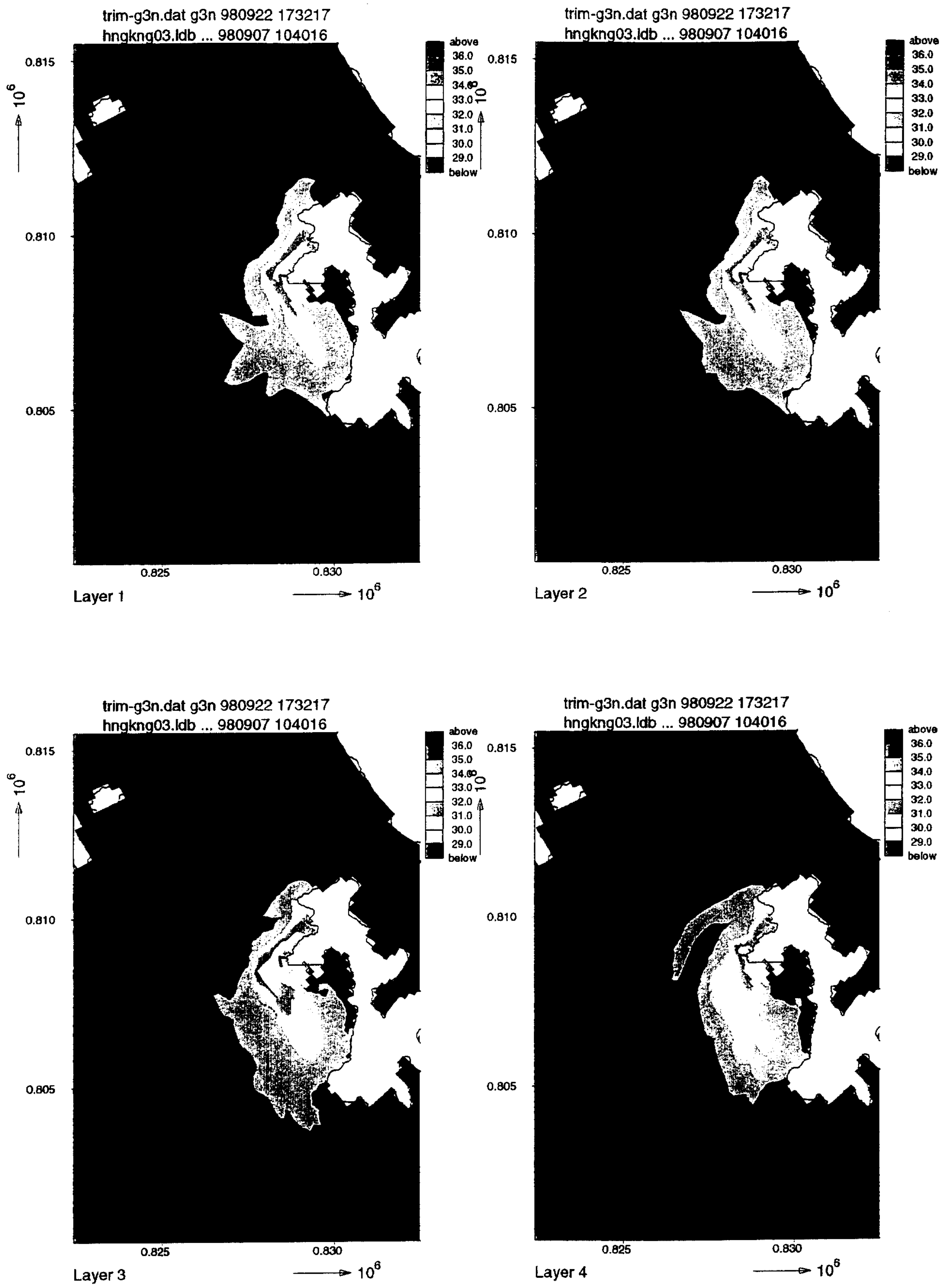
Existing Lamma Island Power Station; Scenario 1
Time series of temperature for 1-14 August 1992 (Wet season)
Pak Kok Coral

1998-09-23
15:15:27

DELFT HYDRAULICS

Fig. 3.1.10

DELFT HYDRAULICS



Extension Lamma Island Power Station; Scenario 2
Maximum temperature for 1-7 August 1992 (Neap tide)
Wet Season; For layers 1 to 4 (layer 1 = surface layer)

1998-09-23
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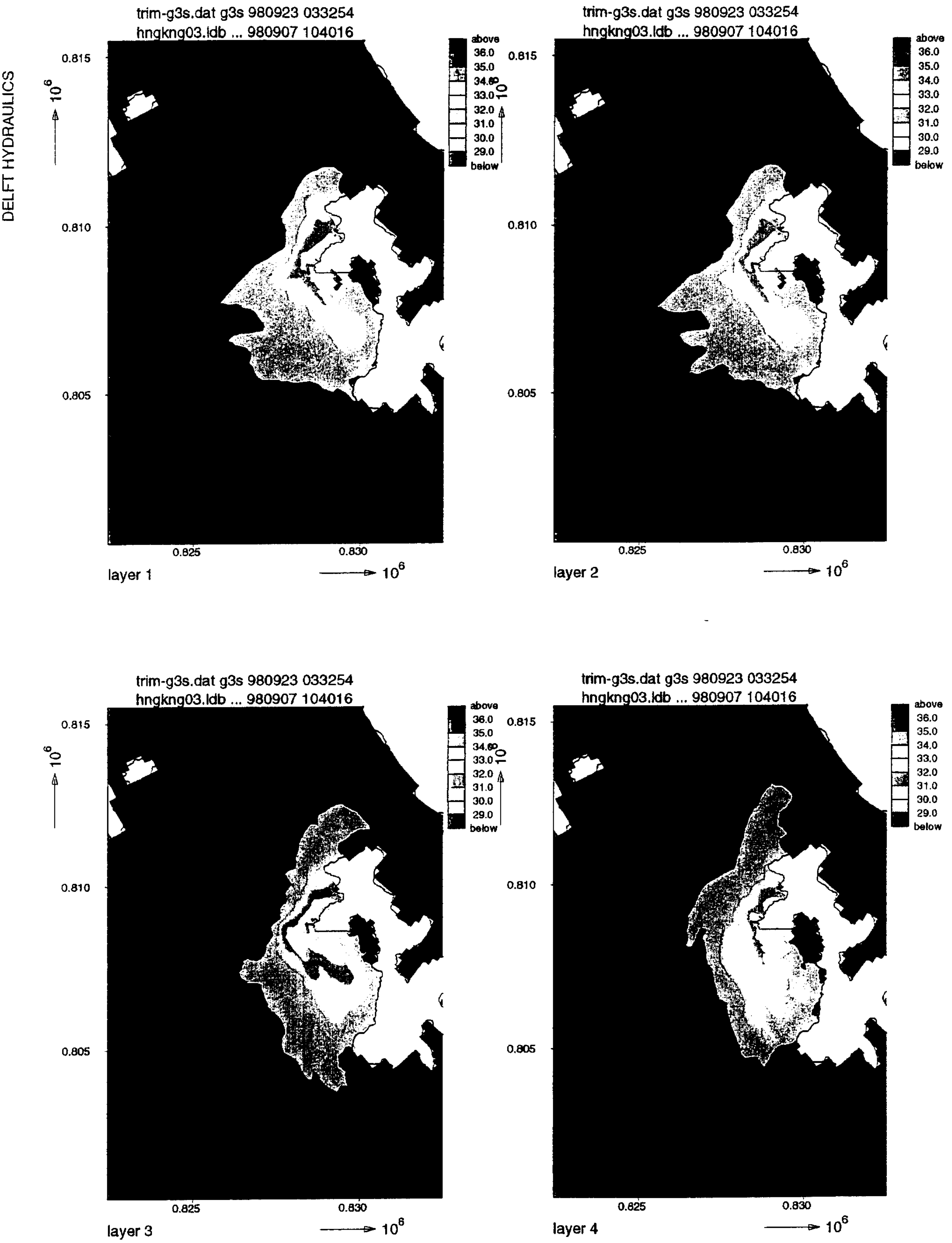
Fig. 3.2.1



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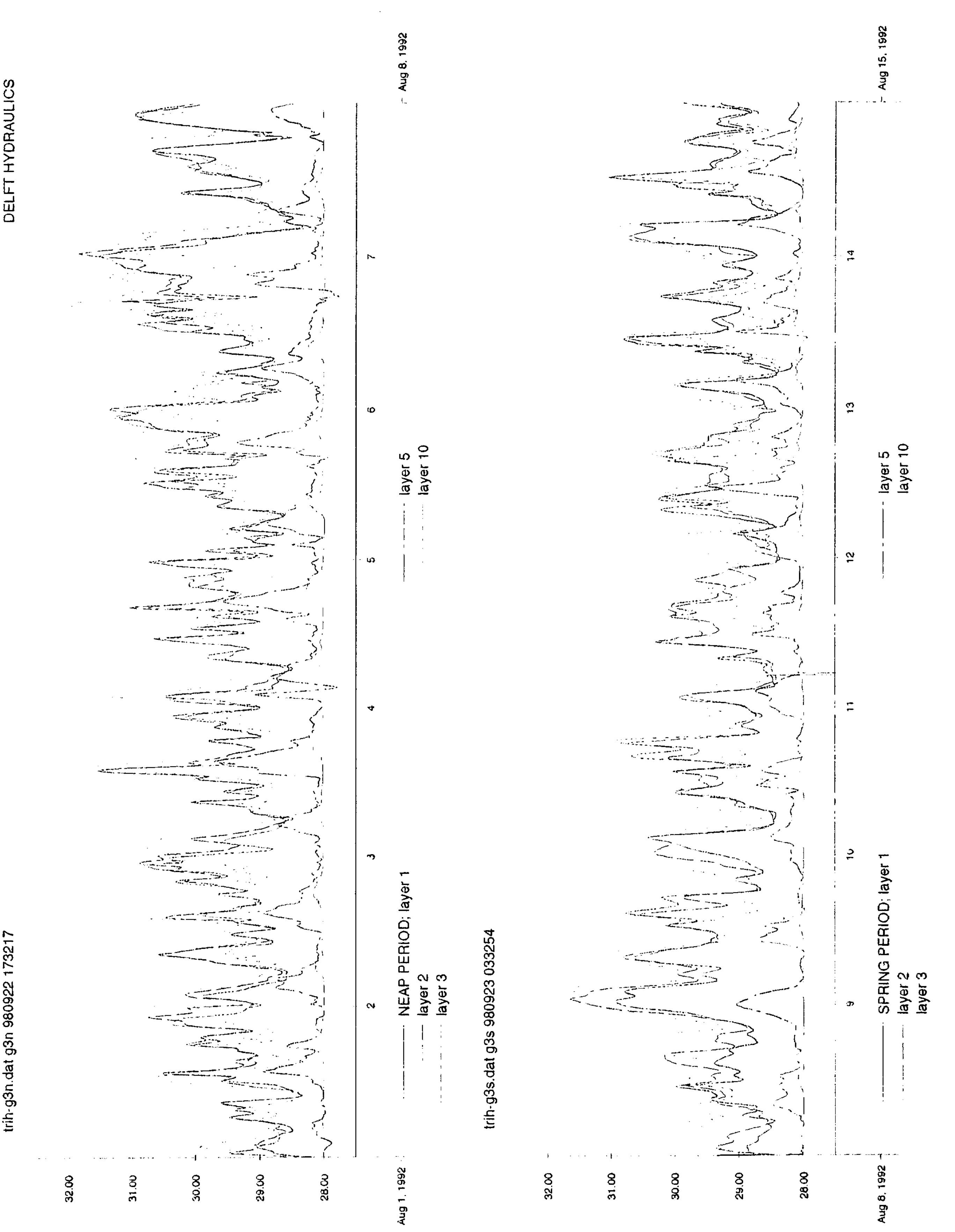
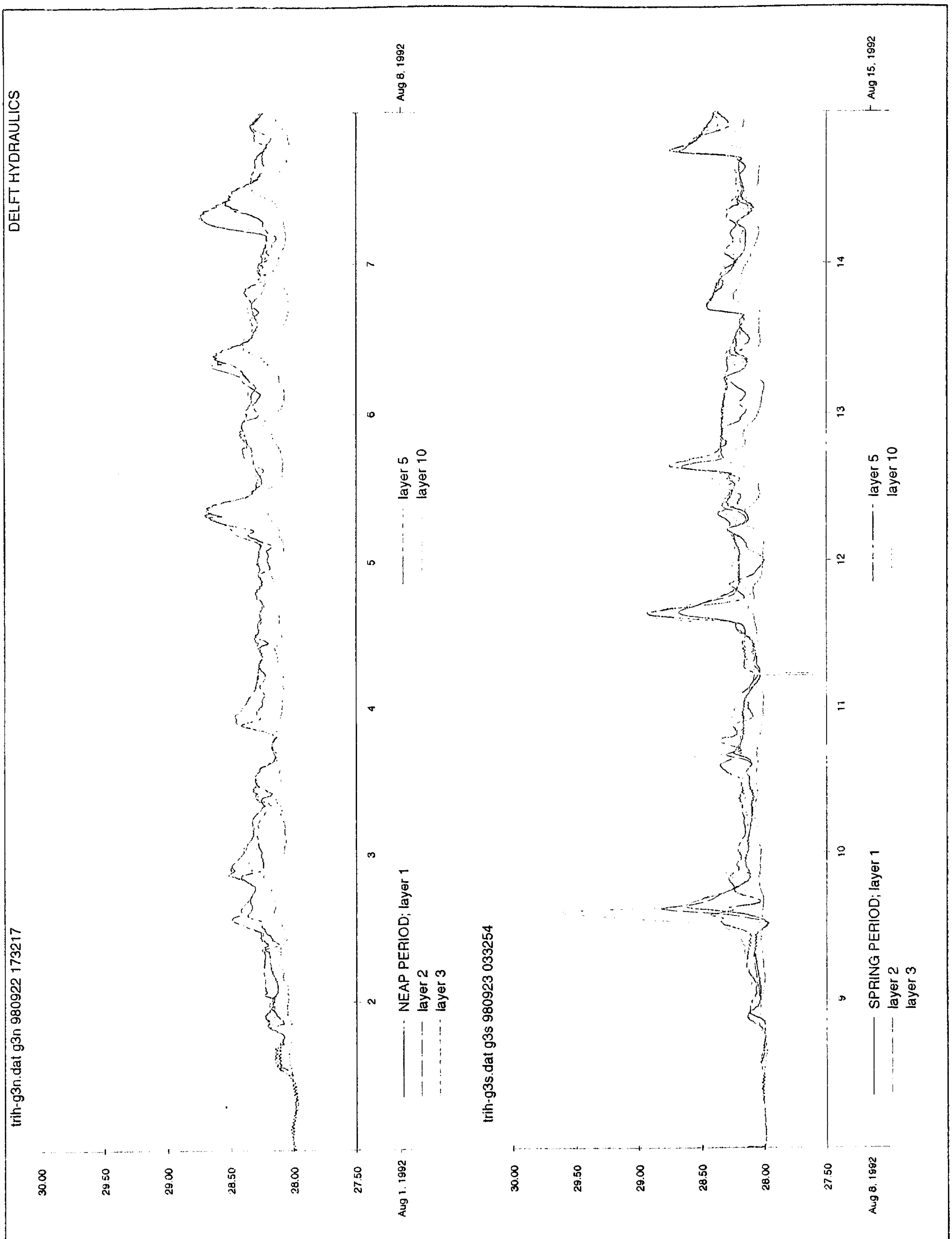


Extension Lamma Island Power Station; Scenario 2
Time series of temperature for 1-14 August 1992 (Wet season)
Outfall Lamma Power extension

1998-09-23
15:53:25

DELFT HYDRAULICS

Fig. 3.2.3



Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 1-14 August 1992 (Wet season) Lamma island Power Intake		1998-09-23 15:21:25
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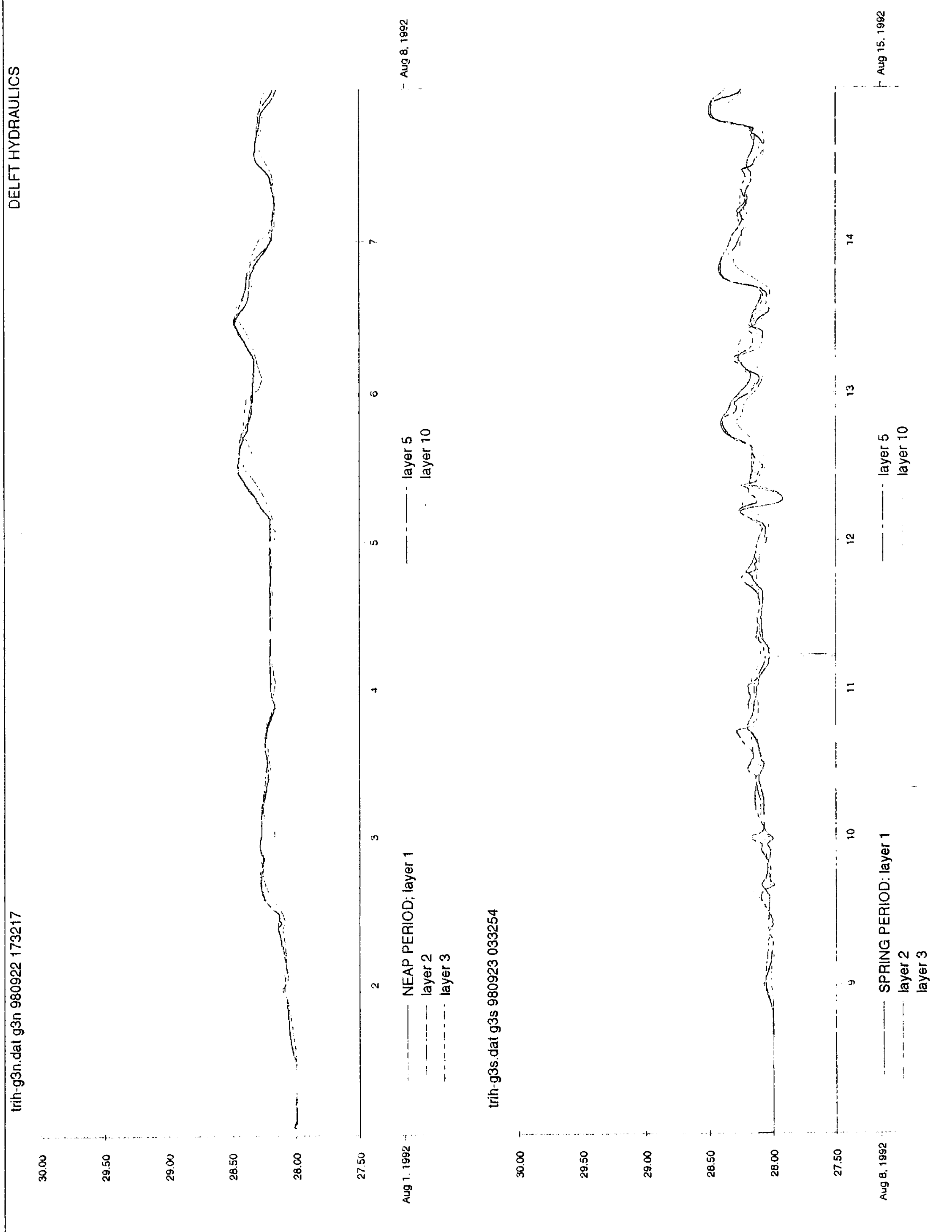

Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 1-14 August 1992 (Wet season) Hung Shing Ye Beach		1998-09-23 15:21:28
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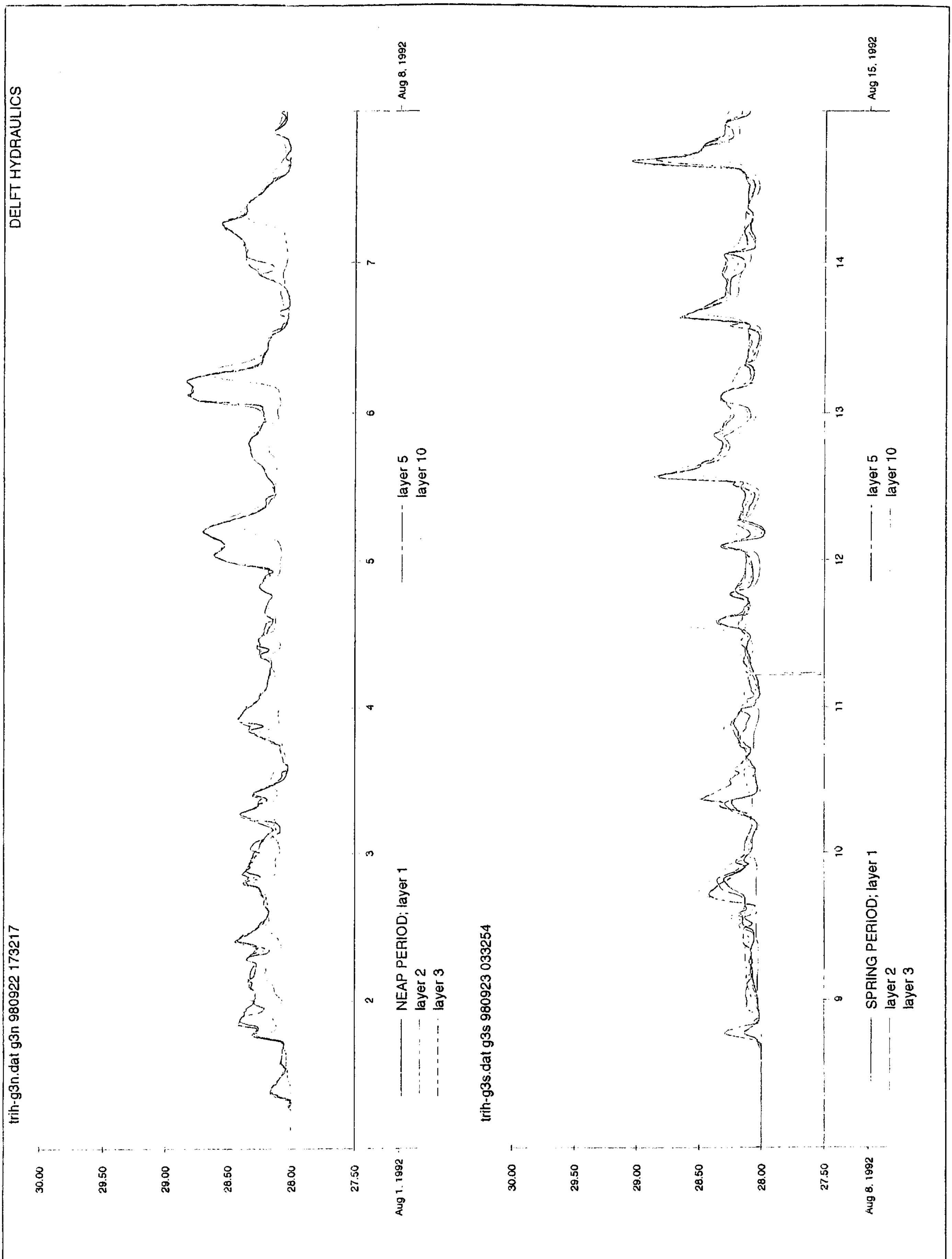

Extension Lamma Island Power Station; Scenario 2
Time series of temperature for 1-14 August 1992 (Wet season)
Lo So Shing Beach

1998-09-23
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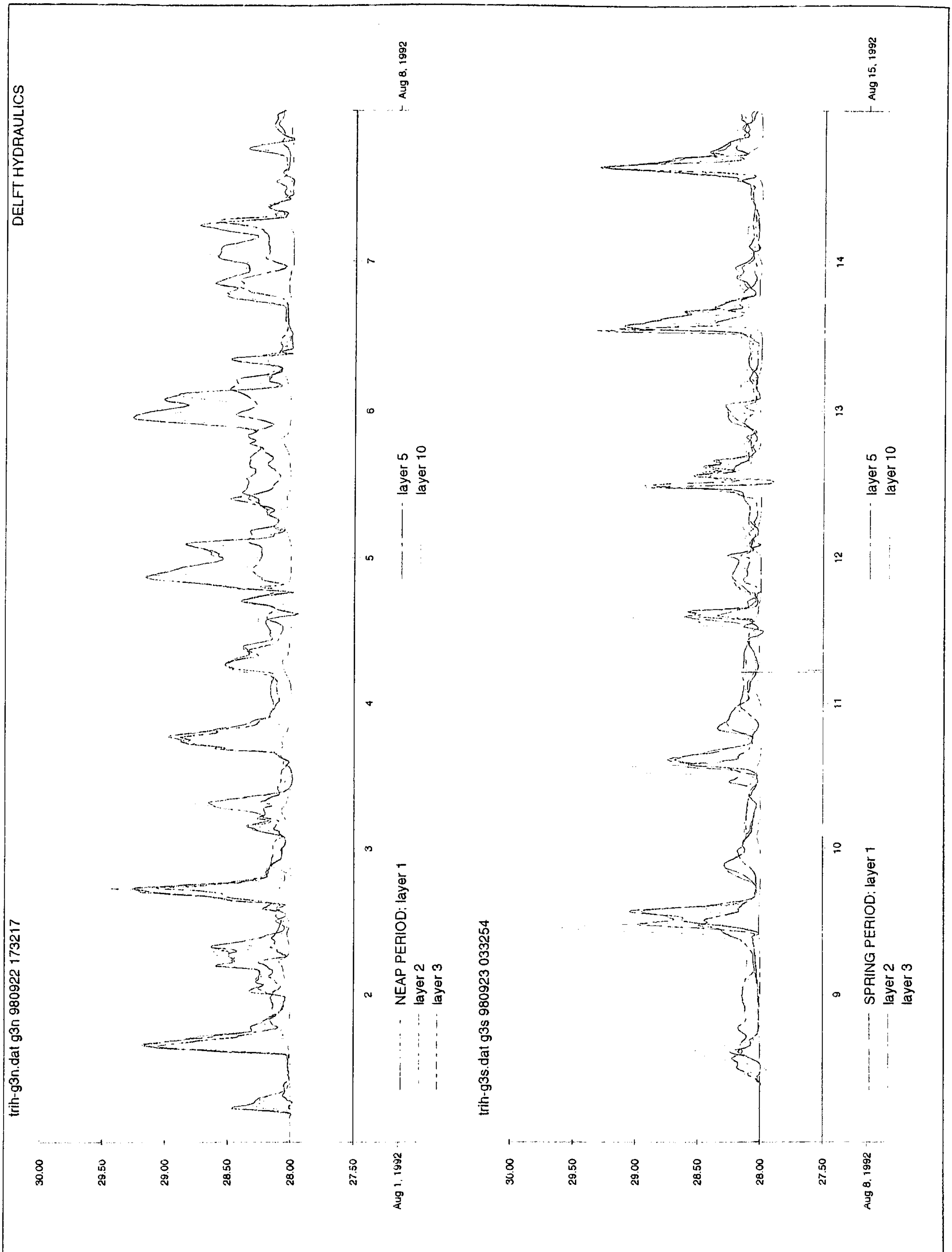
Fig. 3.2.6



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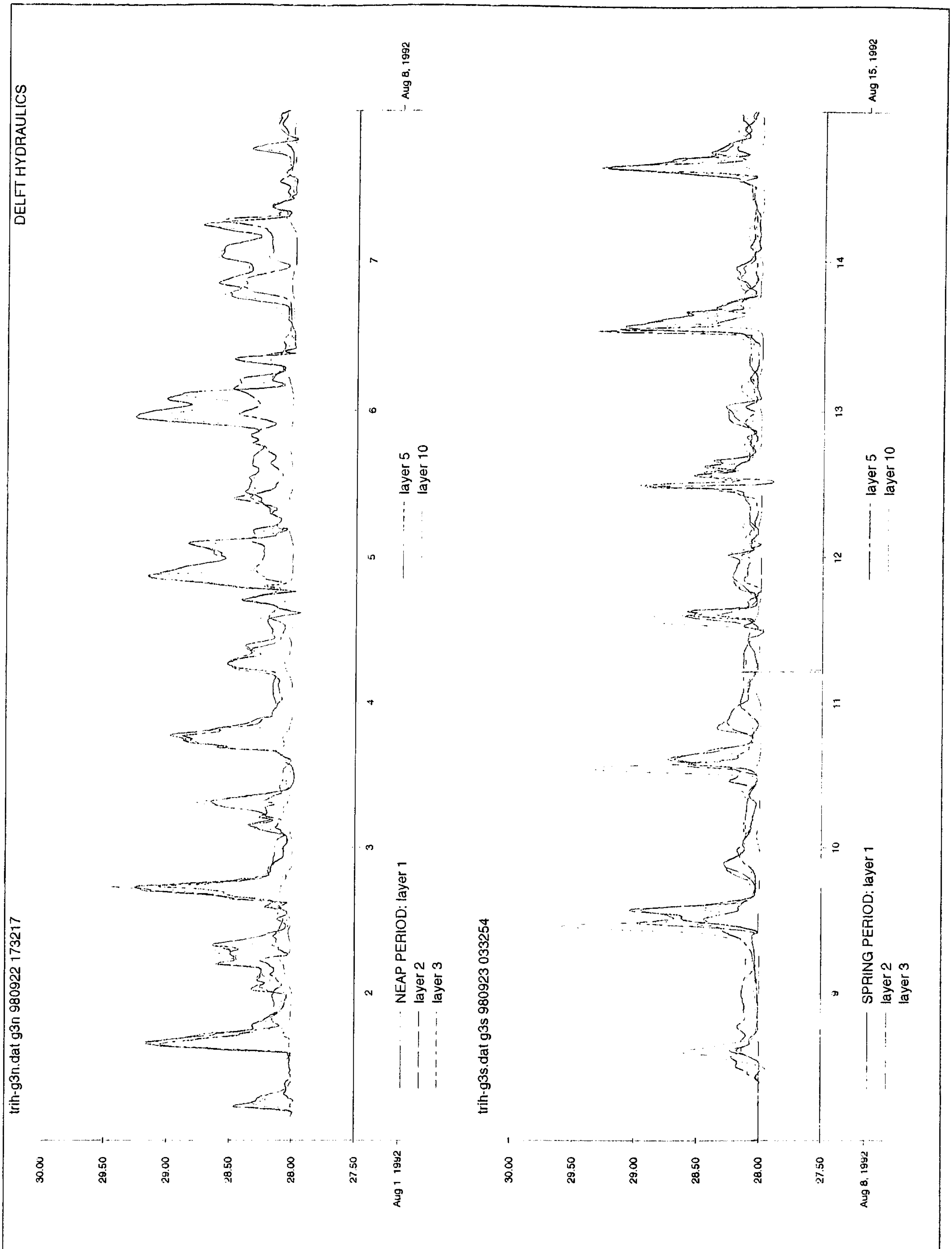

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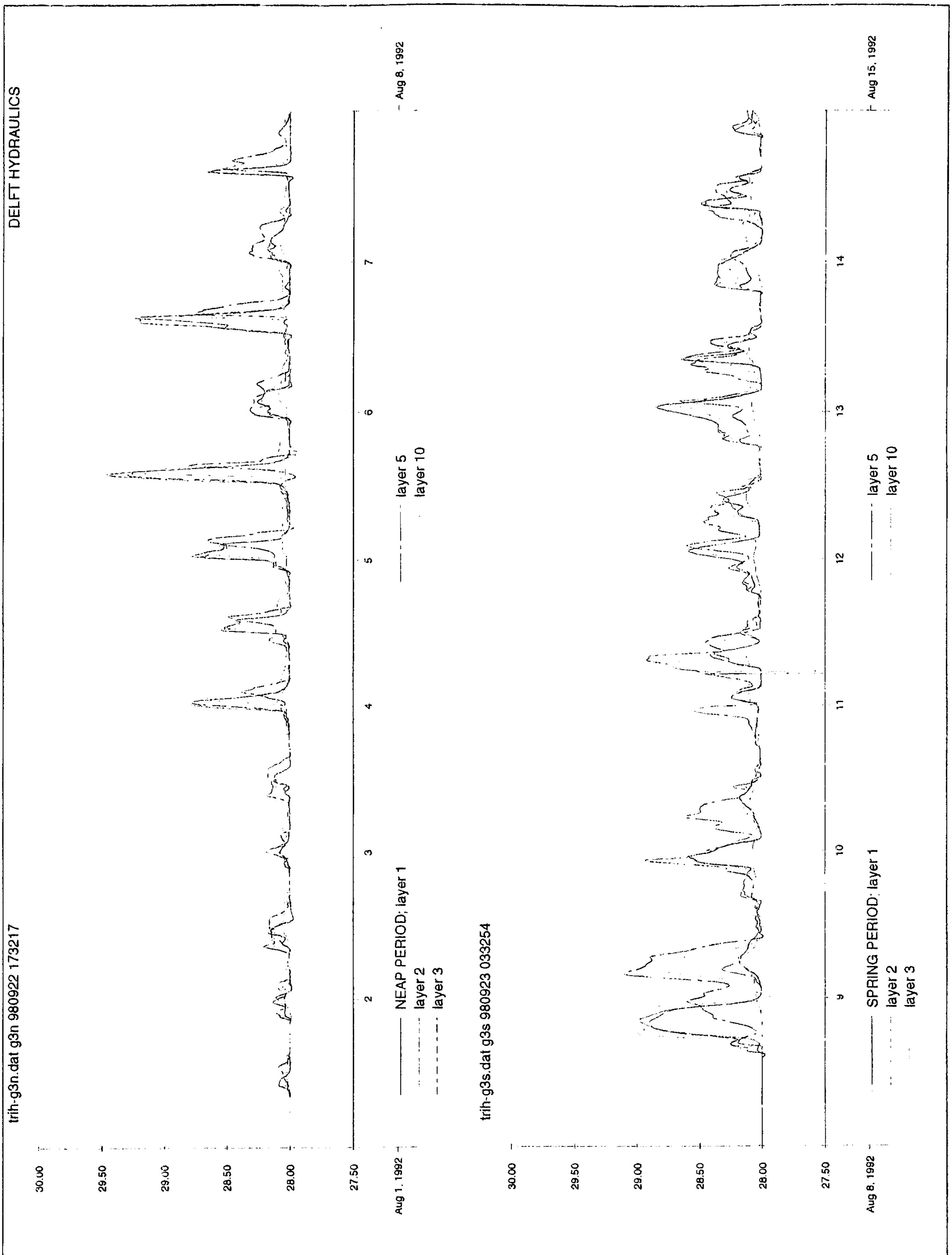

Extension Lamma Island Power Station; Scenario 2
Time series of temperature for 1-14 August 1992 (Wet season)
Shek Kok Tsui Coral

1998-09-23
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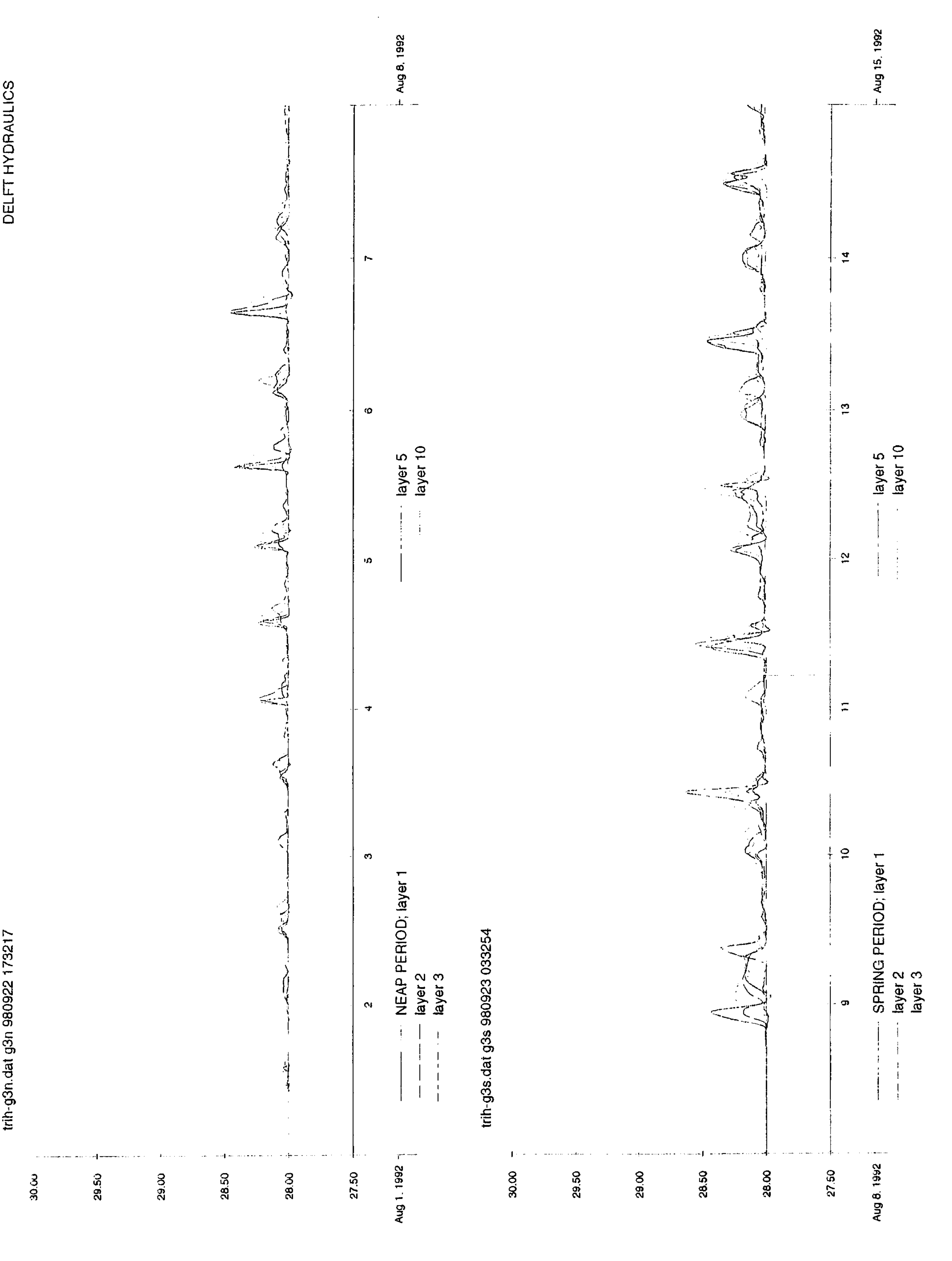
Fig. 3.2.9



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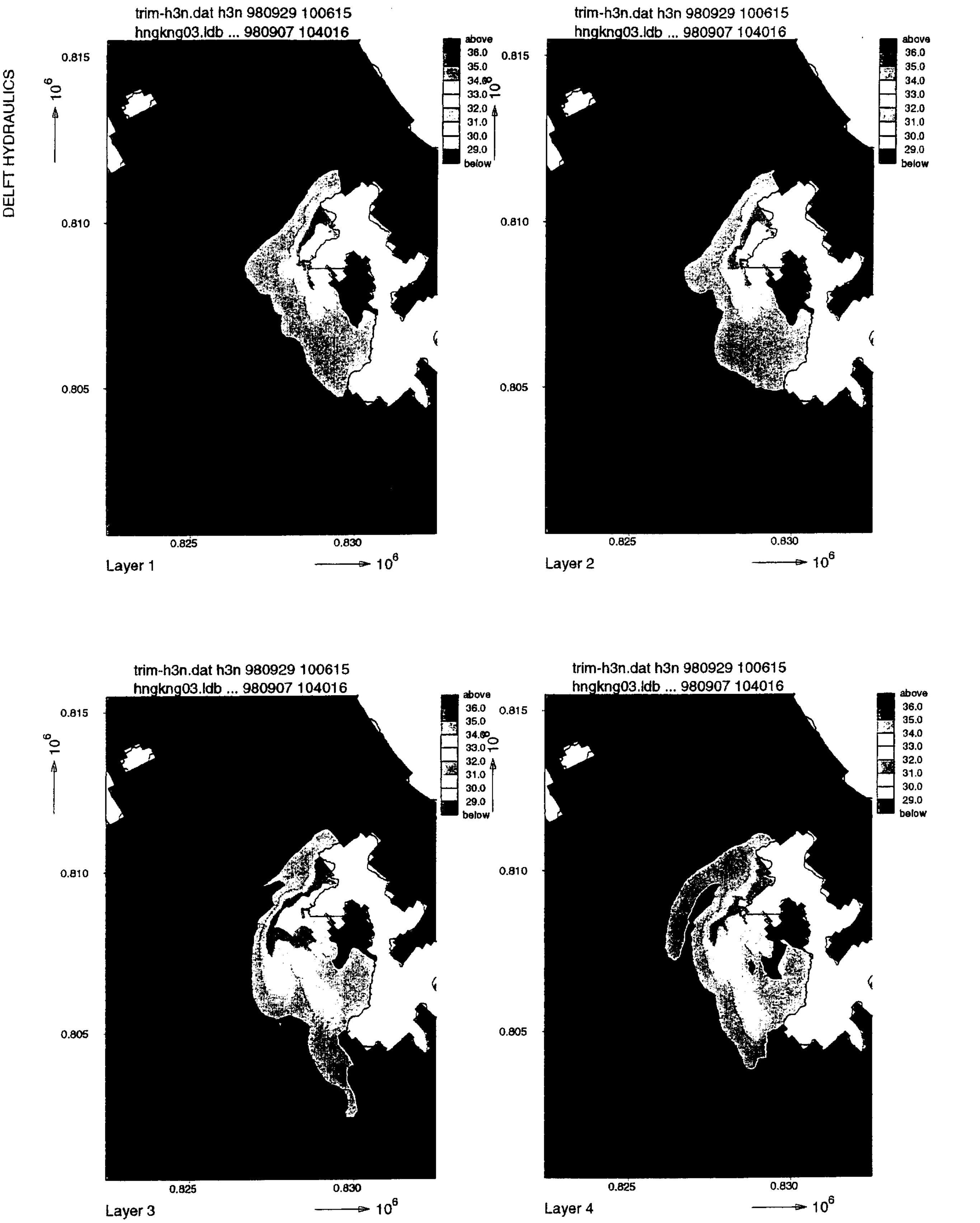
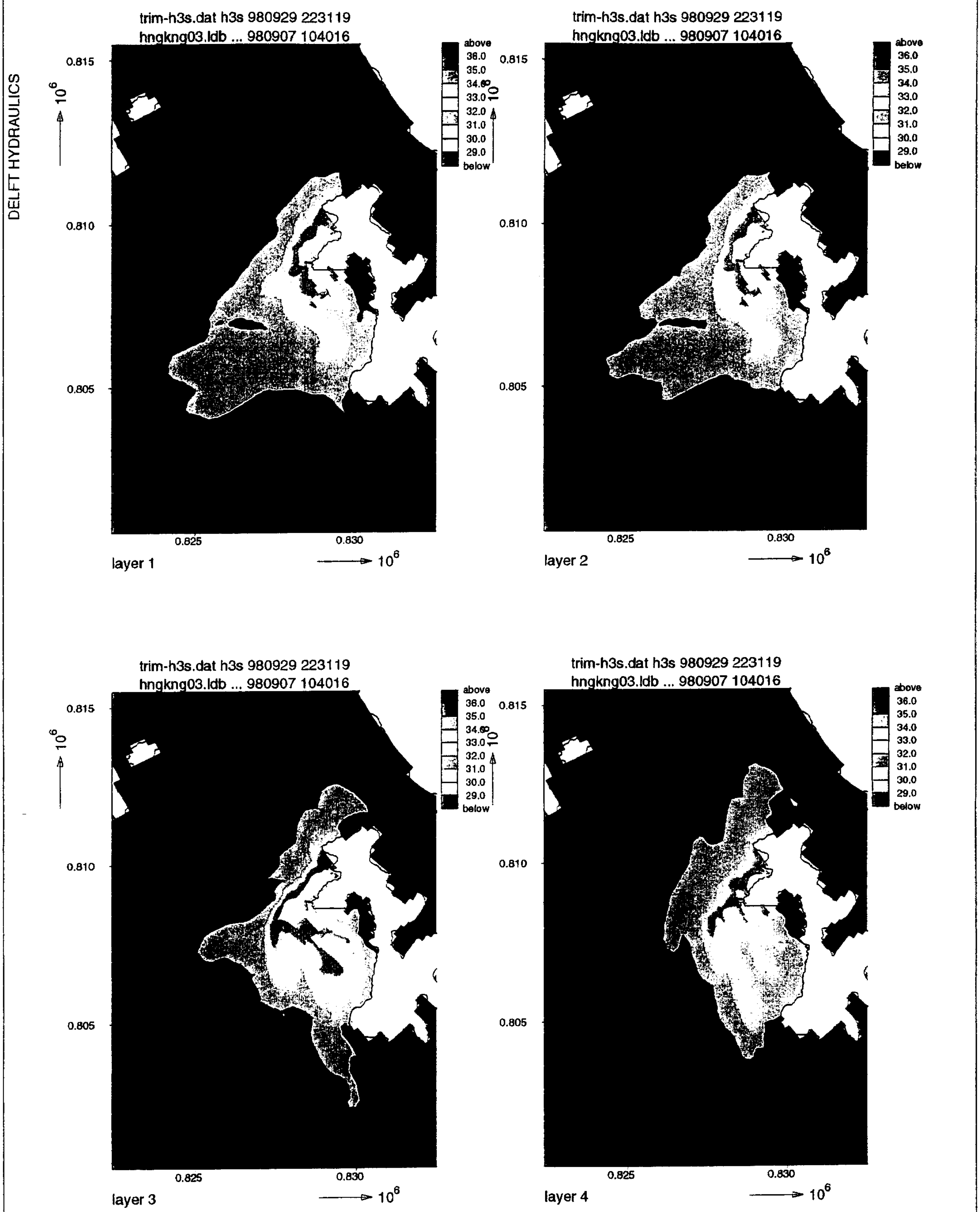


Power Station + WEIF extension; Scenario 3
Maximum temperature for 1-7 August 1992 (Neap tide)
Wet Season; For layers 1 to 4 (layer 1 = surface layer)

1998-10-01
09:19:14

DELFT HYDRAULICS

Fig. 3.3.1



Power Station + WEIF extension; Scenario 3
Maximum temperature for 8-14 August 1992 (Spring tide)
Wet Season; For layers 1 to 4 (layer 1 = surface layer)

1998-10-01
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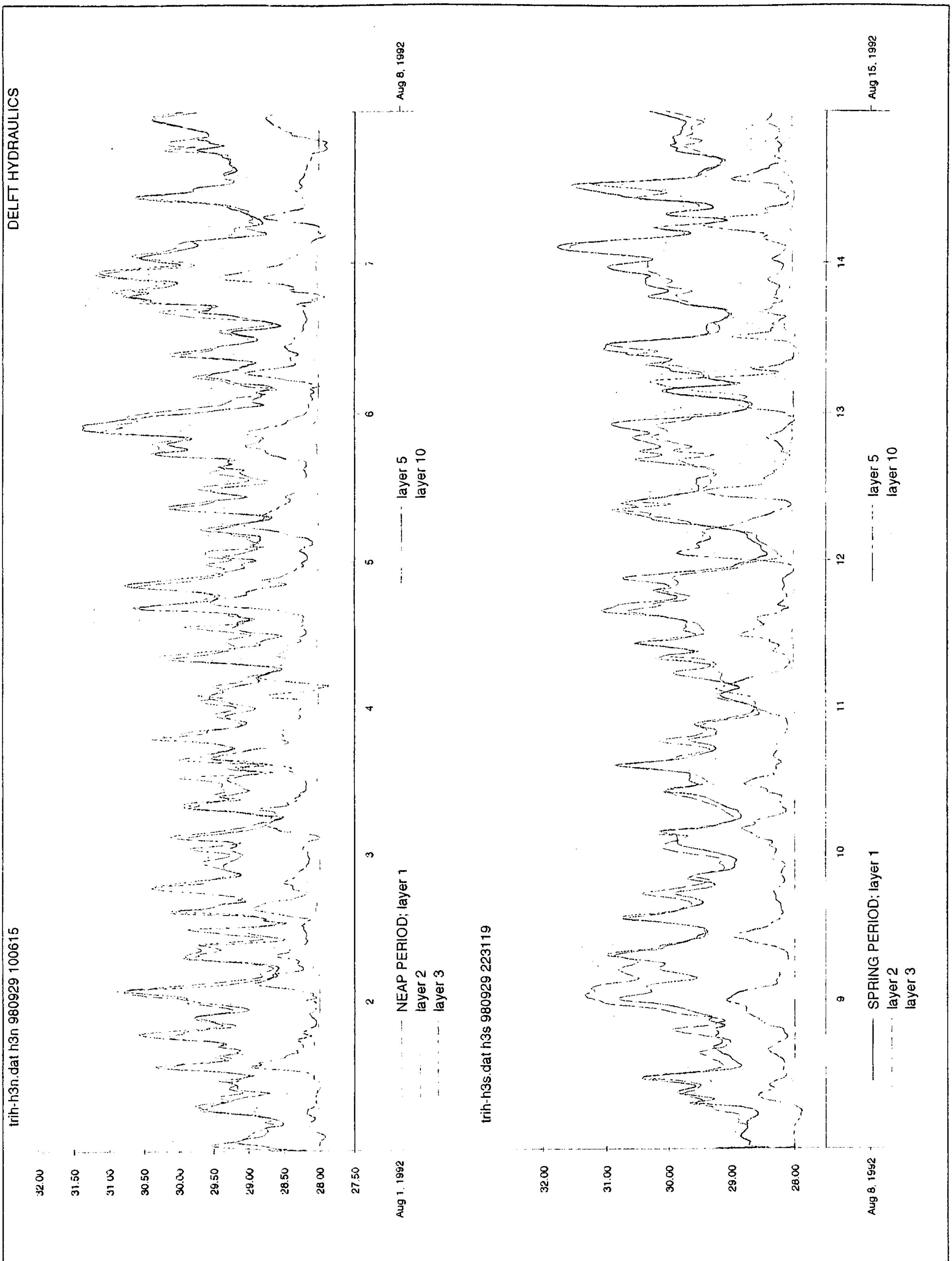
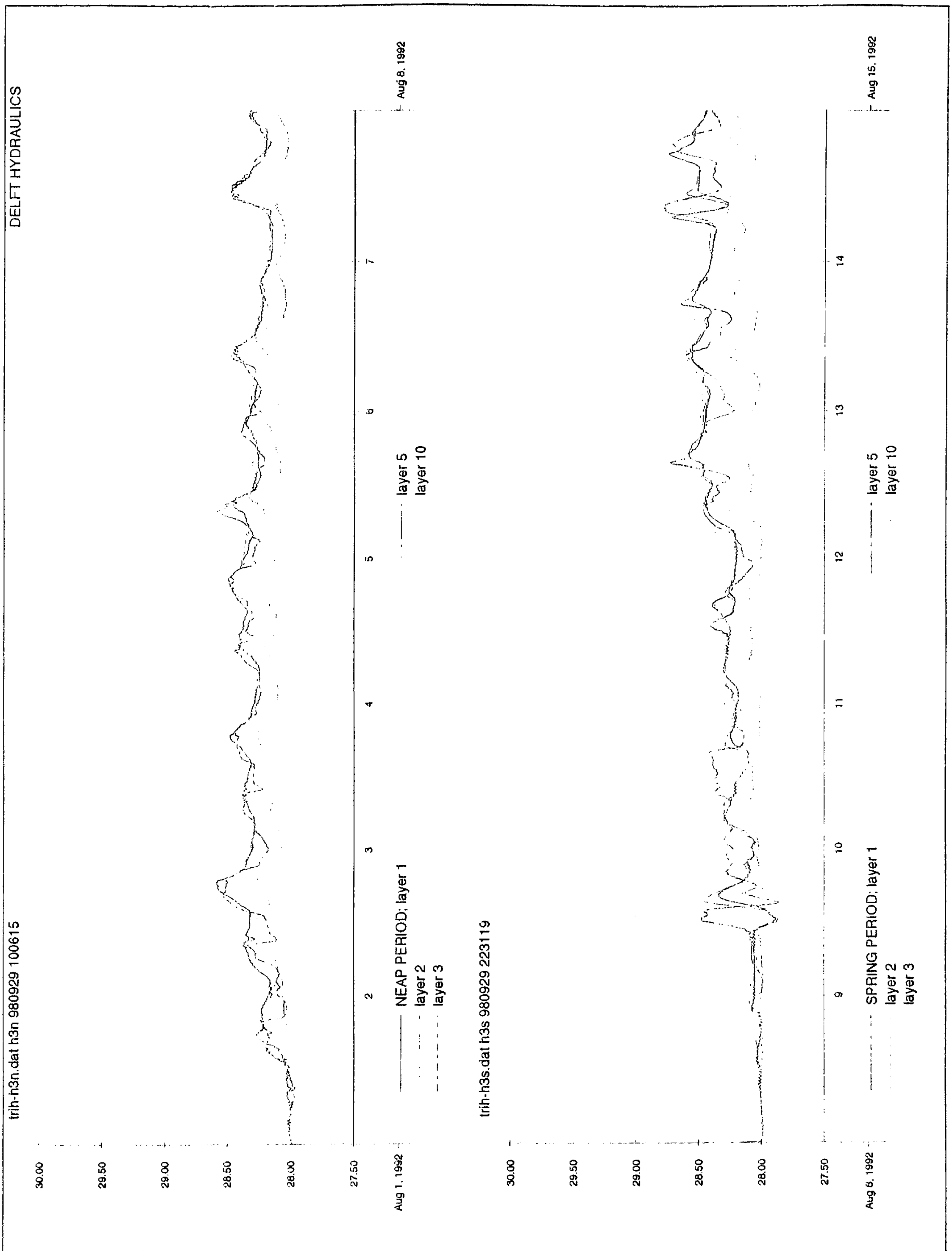
Fig. 3.3.2



Power Station + WEIF extension; Scenario 3 Time series of temperature for 1-14 August 1992 (Wet season) Outfall Lamma Power extension	1998-10-01 09:52:25
DELFT HYDRAULICS	Fig. 3.3.3

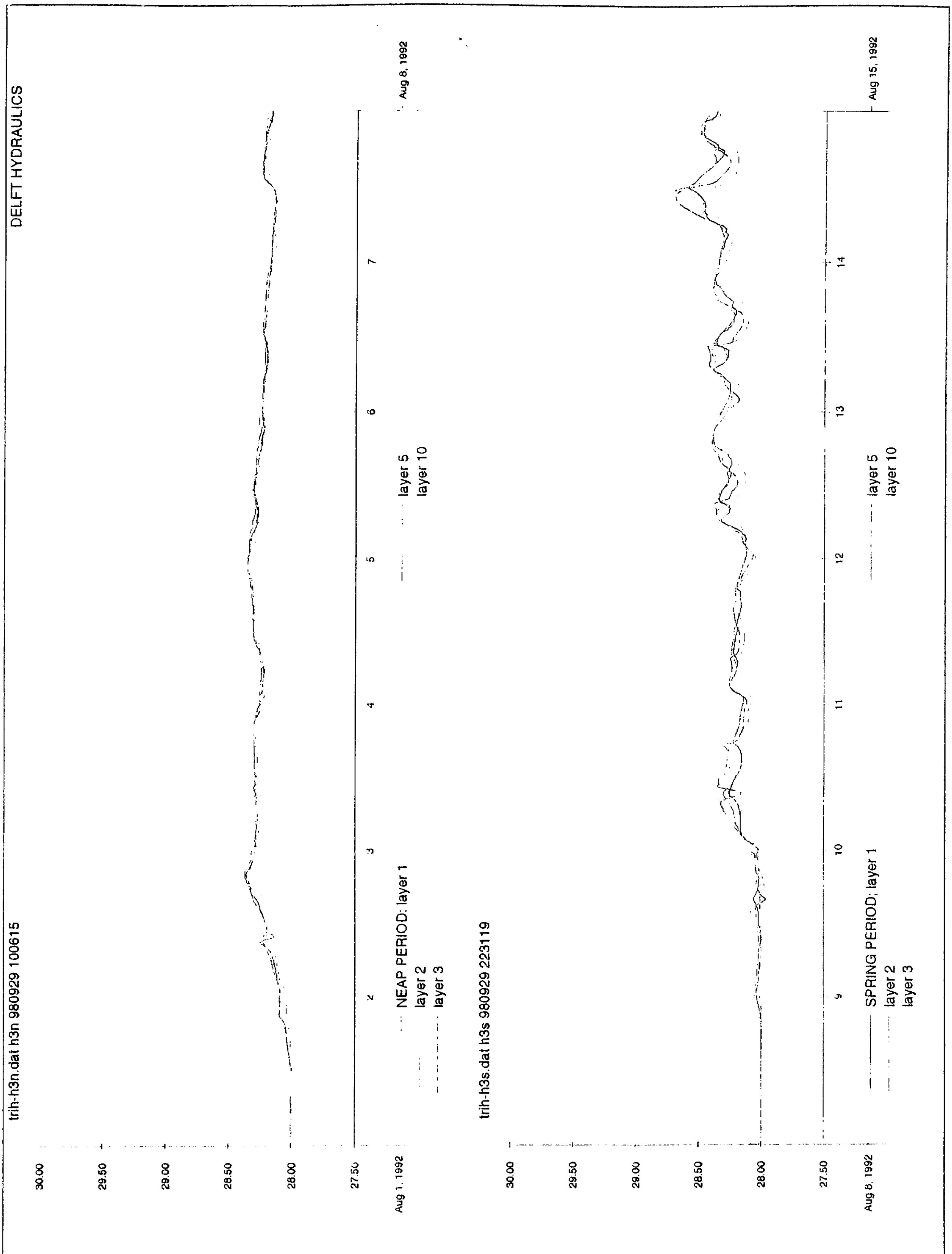


Power Station + WEIF extension; Scenario 3
Time series of temperature for 1-14 August 1992 (Wet season)
Lamma island Power Intake

1998-10-01
09:52:28

DELFT HYDRAULICS

Fig. 3.3.4



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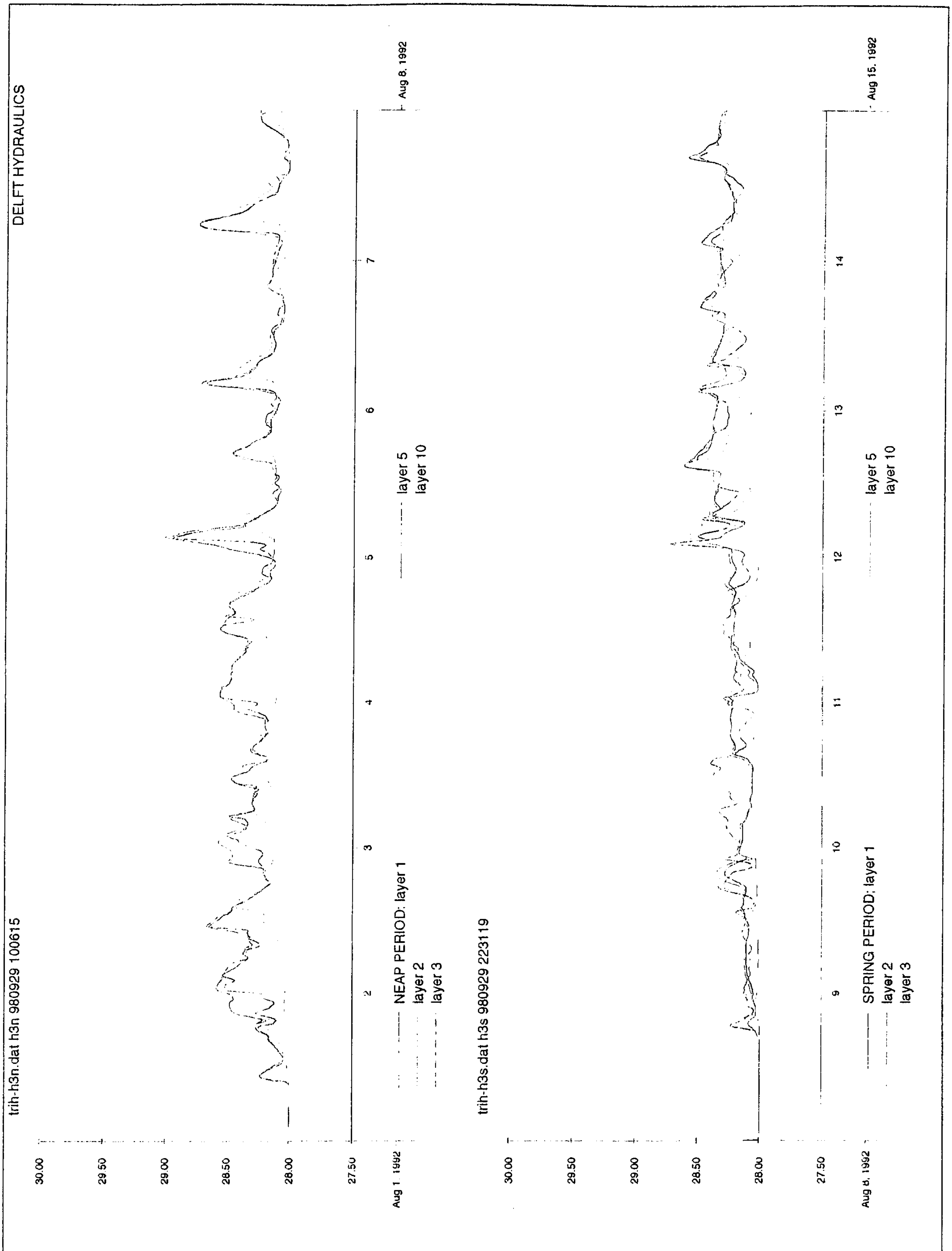

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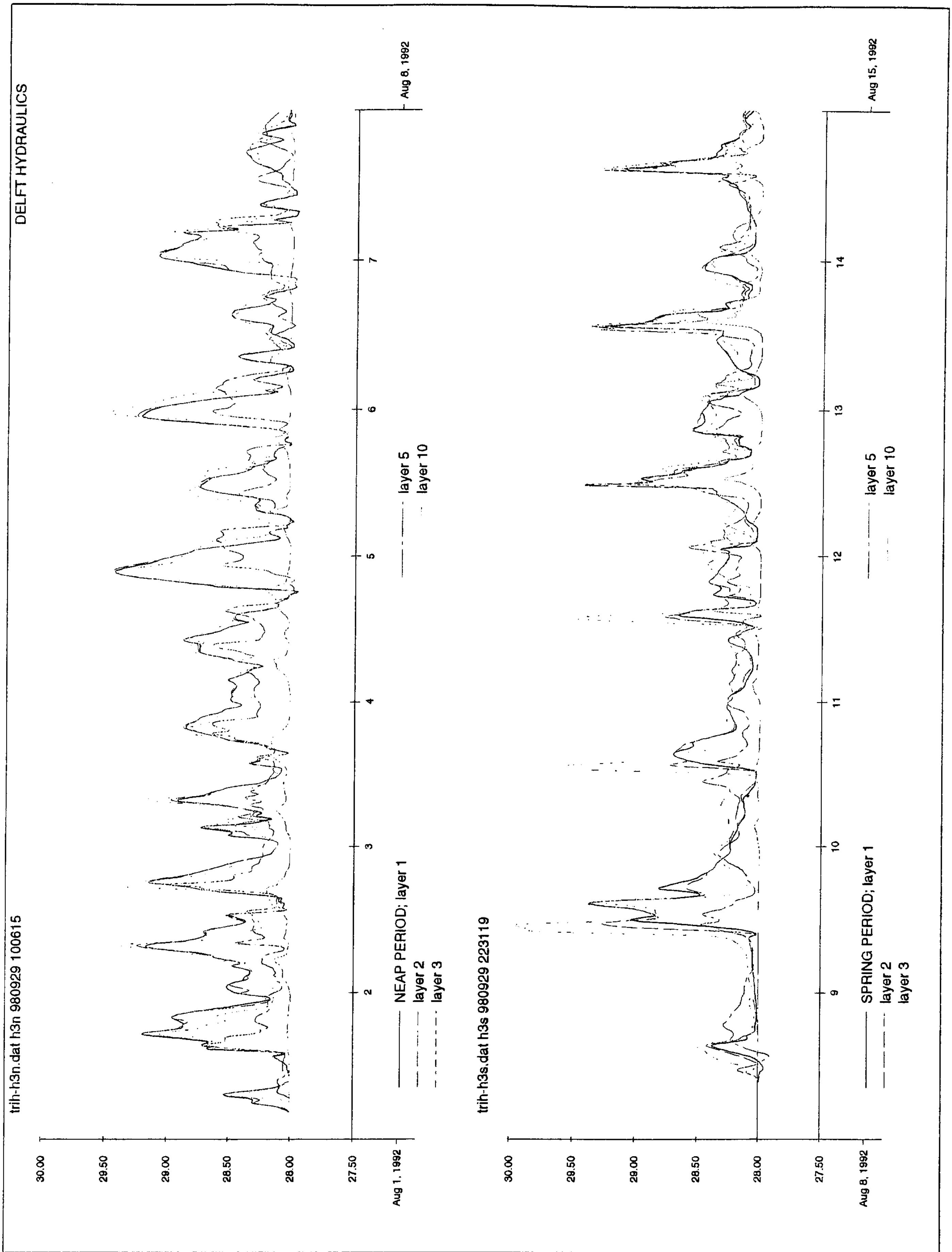

Power Station + WEIF extension; Scenario 3 Time series of temperature for 1-14 August 1992 (Wet season) South Lamma Marine Park 1		1998-10-01 09:52:36
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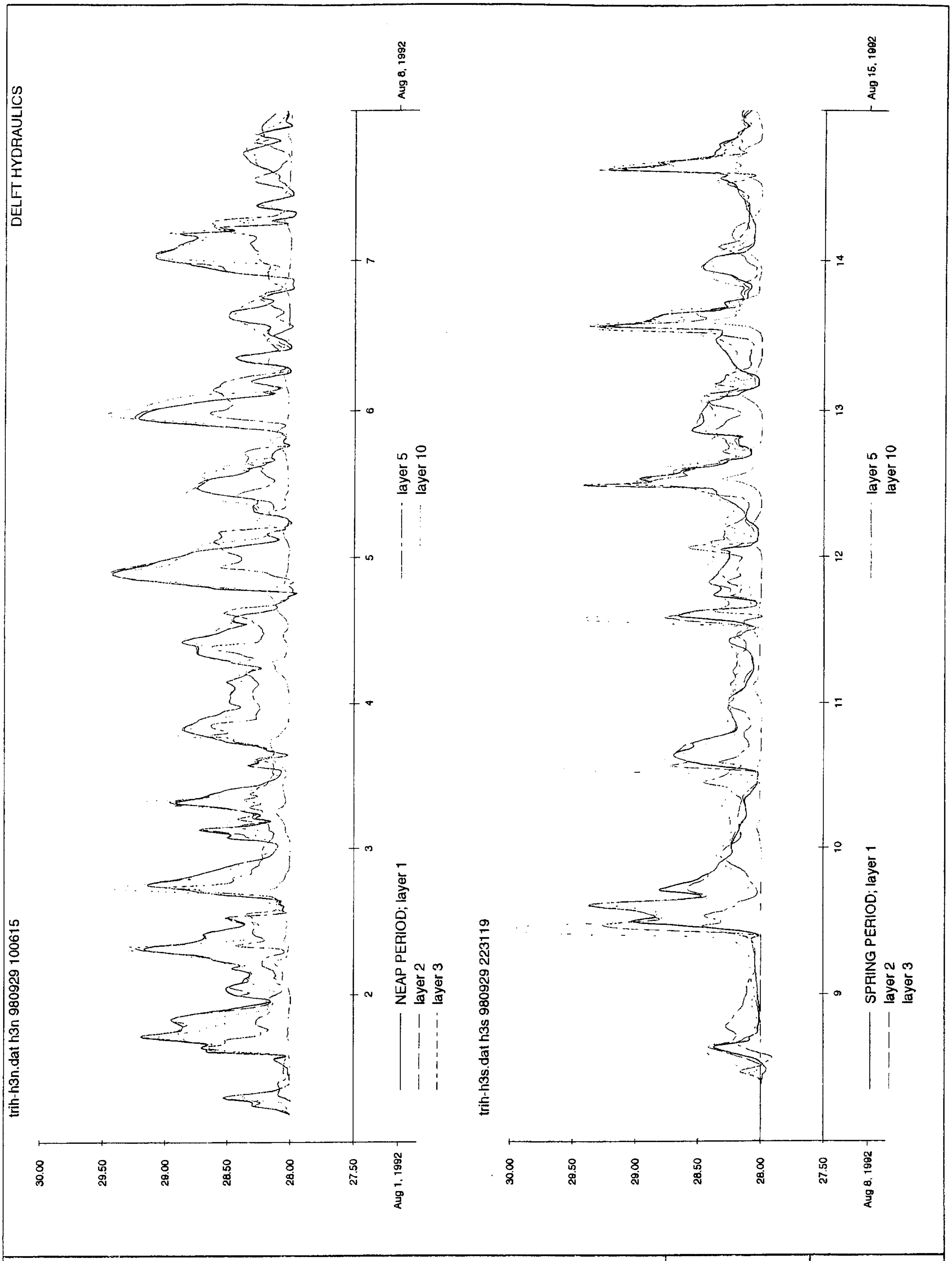
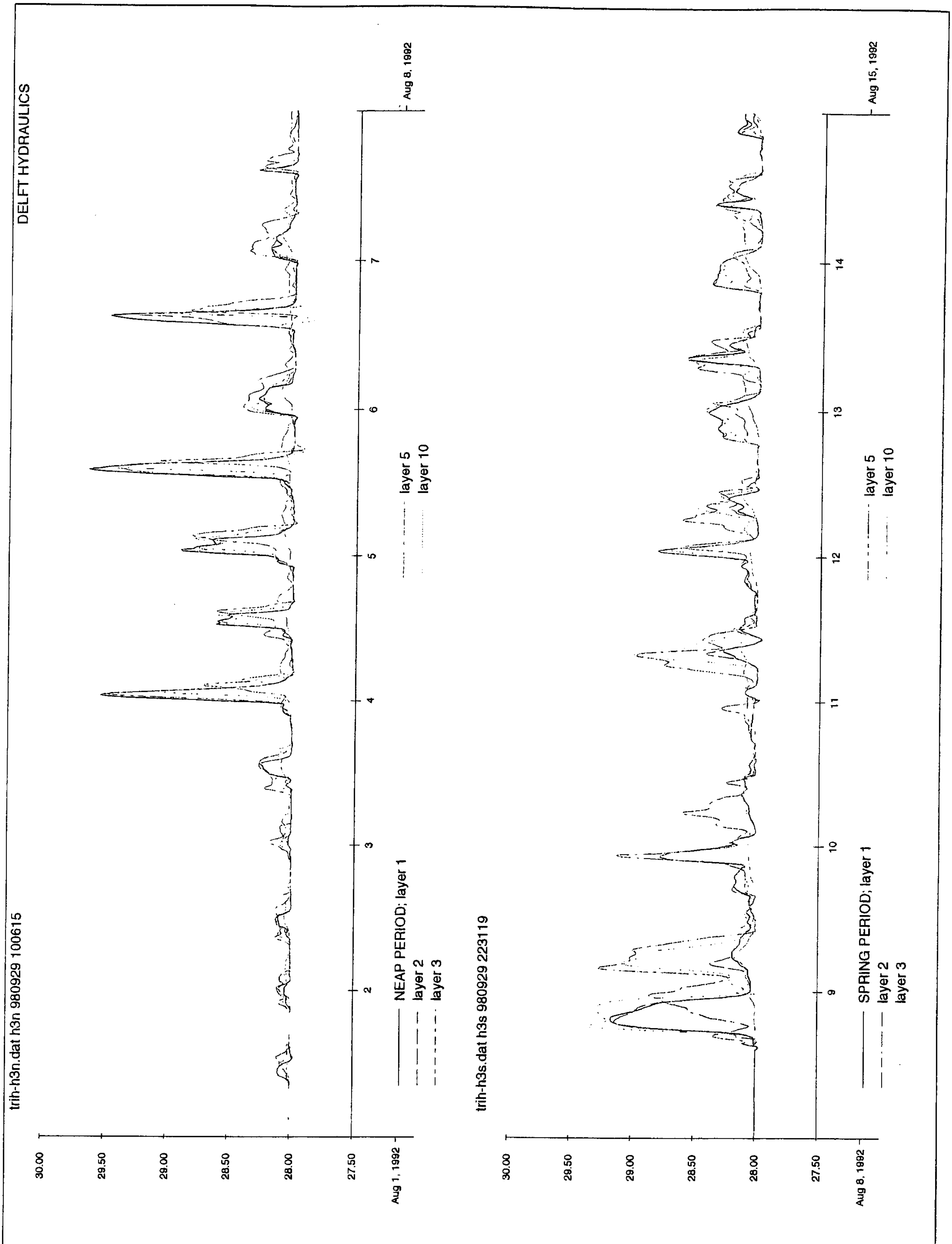
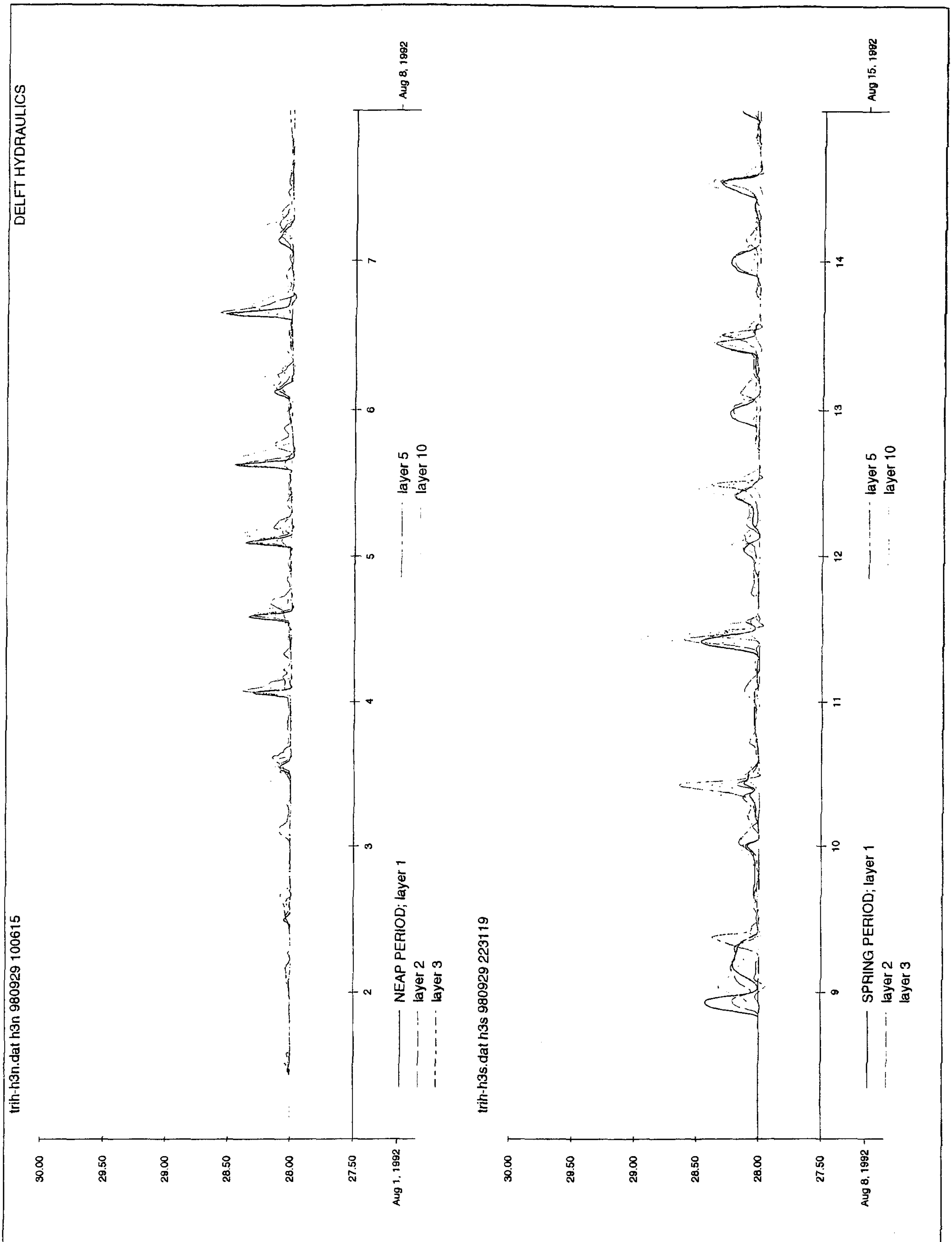


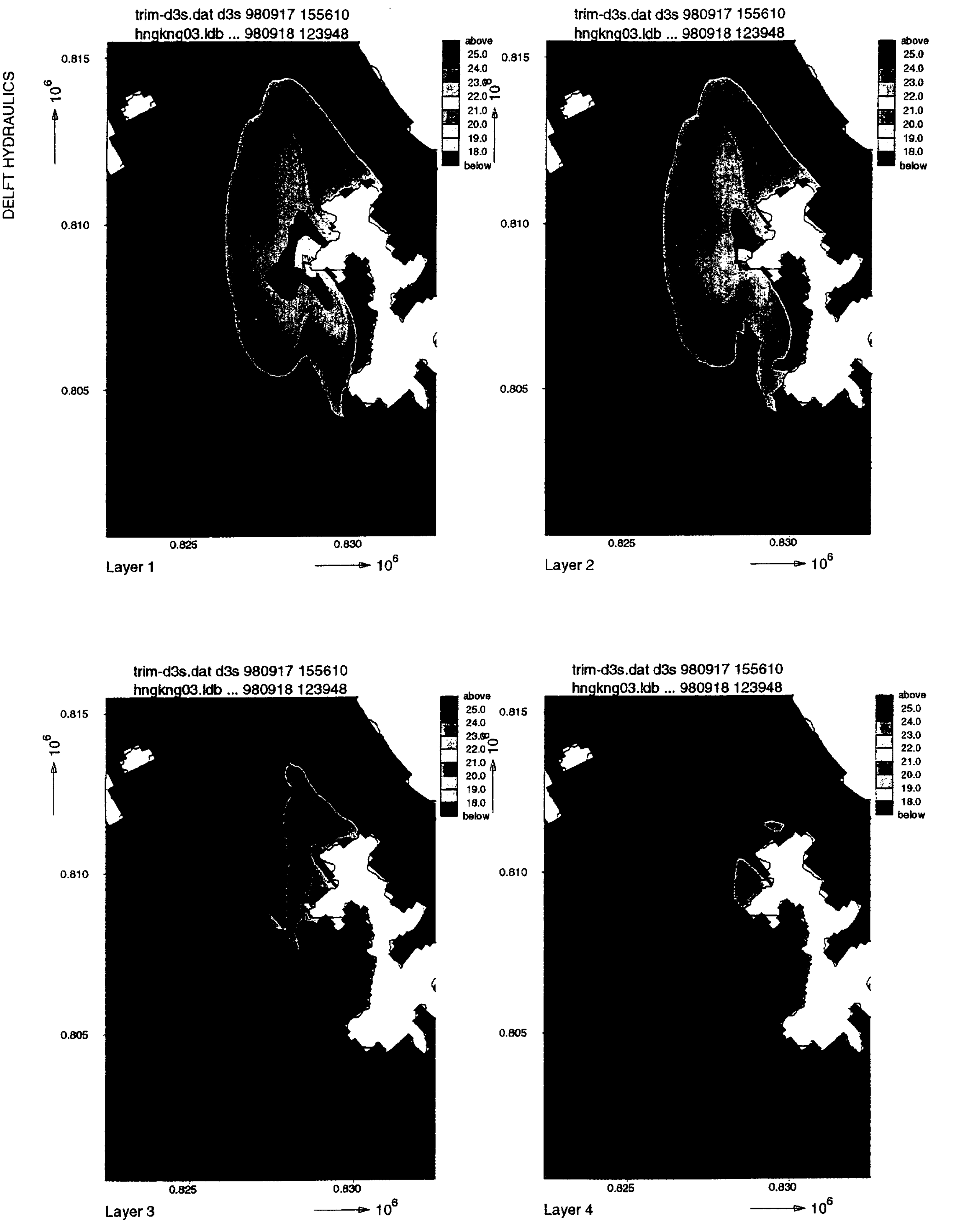
Power Station + WEIF extension; Scenario 3 Time series of temperature for 1-14 August 1992 (Wet season) South Lamma Marine Park 2		1998-10-01 09:52:40
DELFT HYDRAULICS		Fig. 3.3.8



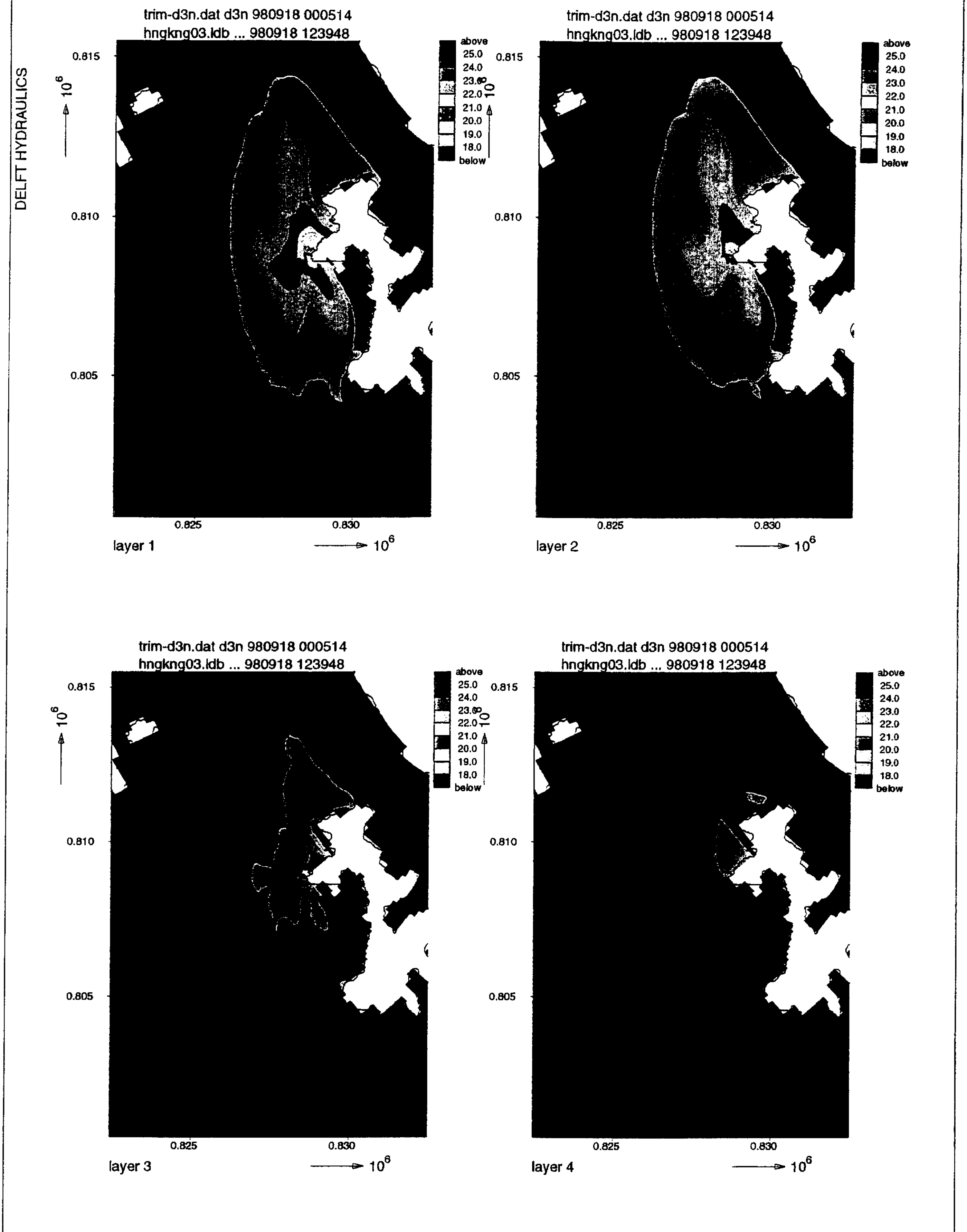
Power Station + WEIF extension; Scenario 3 Time series of temperature for 1-14 August 1992 (Wet season) Shek Kok Tsui Coral		1998-10-01 09:52:43
DELFT HYDRAULICS		Fig. 3.3.9



Power Station + WEIF extension; Scenario 3 *Time series of temperature for 1-14 August 1992 (Wet season)* Pak Kok Coral		1998-10-01 09:52:49
DELFT HYDRAULICS		**Fig. 3.3.10**



Existing Lamma Island Power Station; Scenario 1 Maximum temperature for 6-12 January 1993 (Spring tide) Dry Season; For layers 1 to 4 (layer 1 = surface layer)		1998-09-23 13:01:32
DELFT HYDRAULICS		Fig. 4.1.1

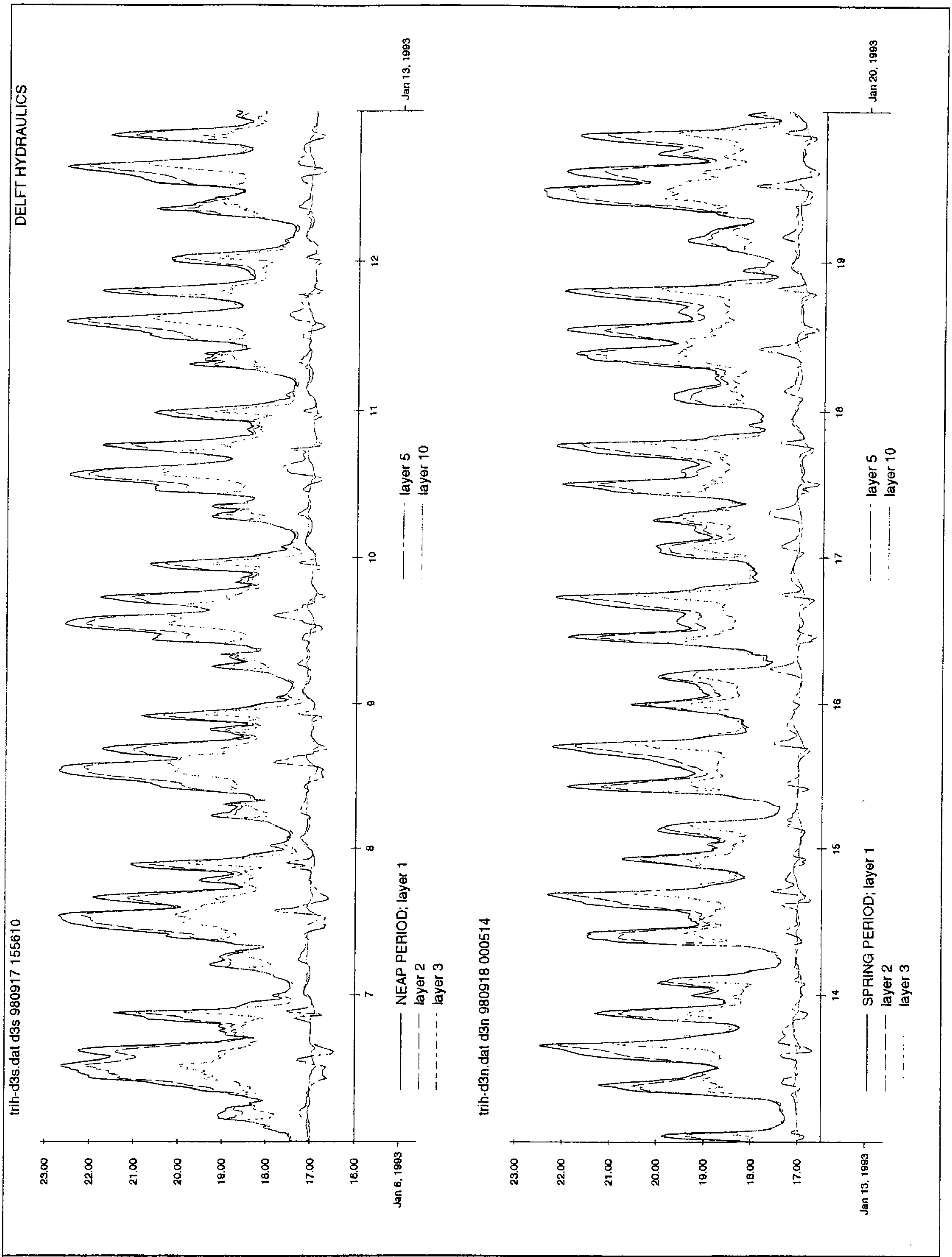


Existing Lamma Island Power Station; Scenario 1
Maximum temperature for 13-19 January 1993 (Neap tide)
Dry Season; For layers 1 to 4 (layer 1 = surface layer)

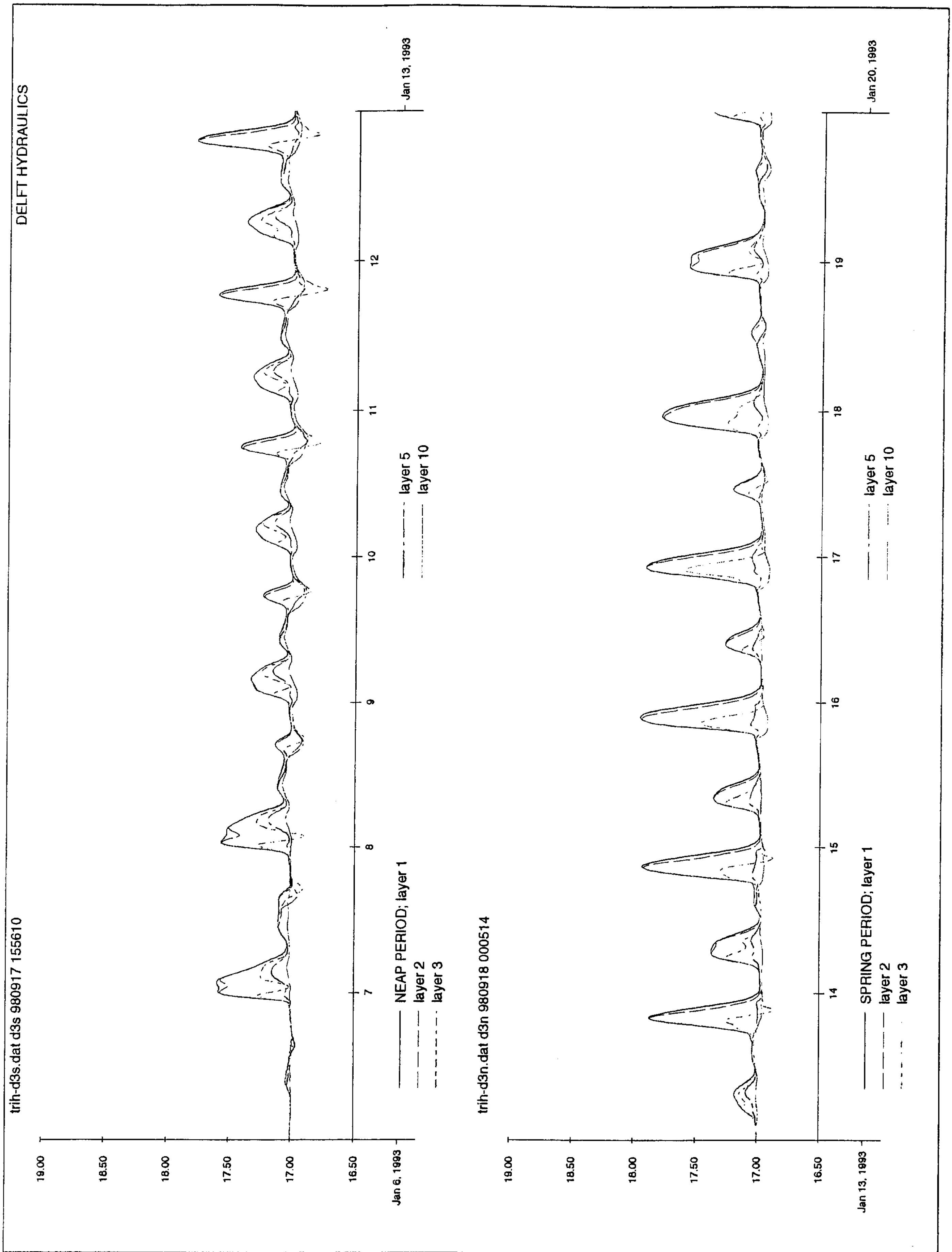
1998-09-23
13:01:37

DELFT HYDRAULICS

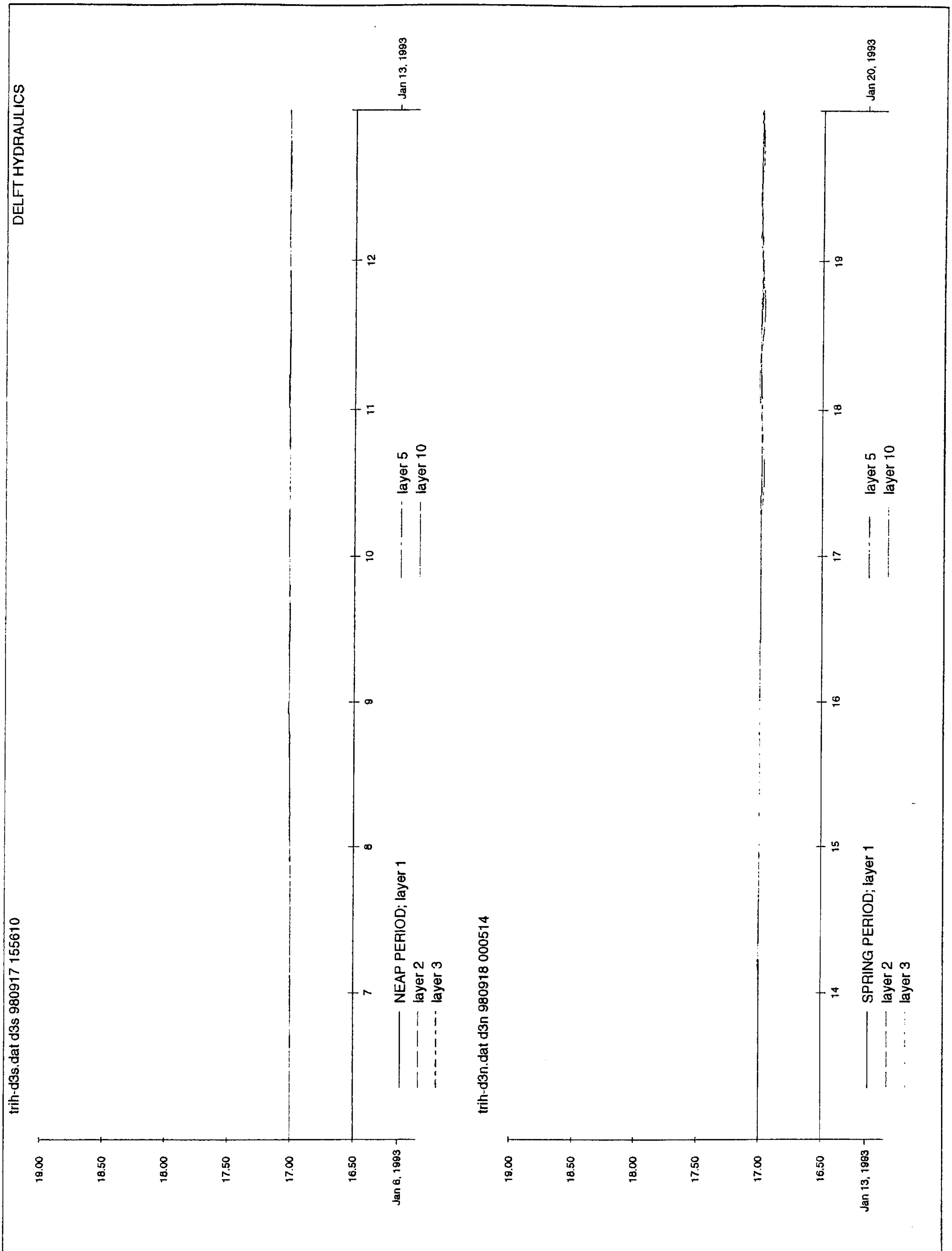
Fig. 4.1.2



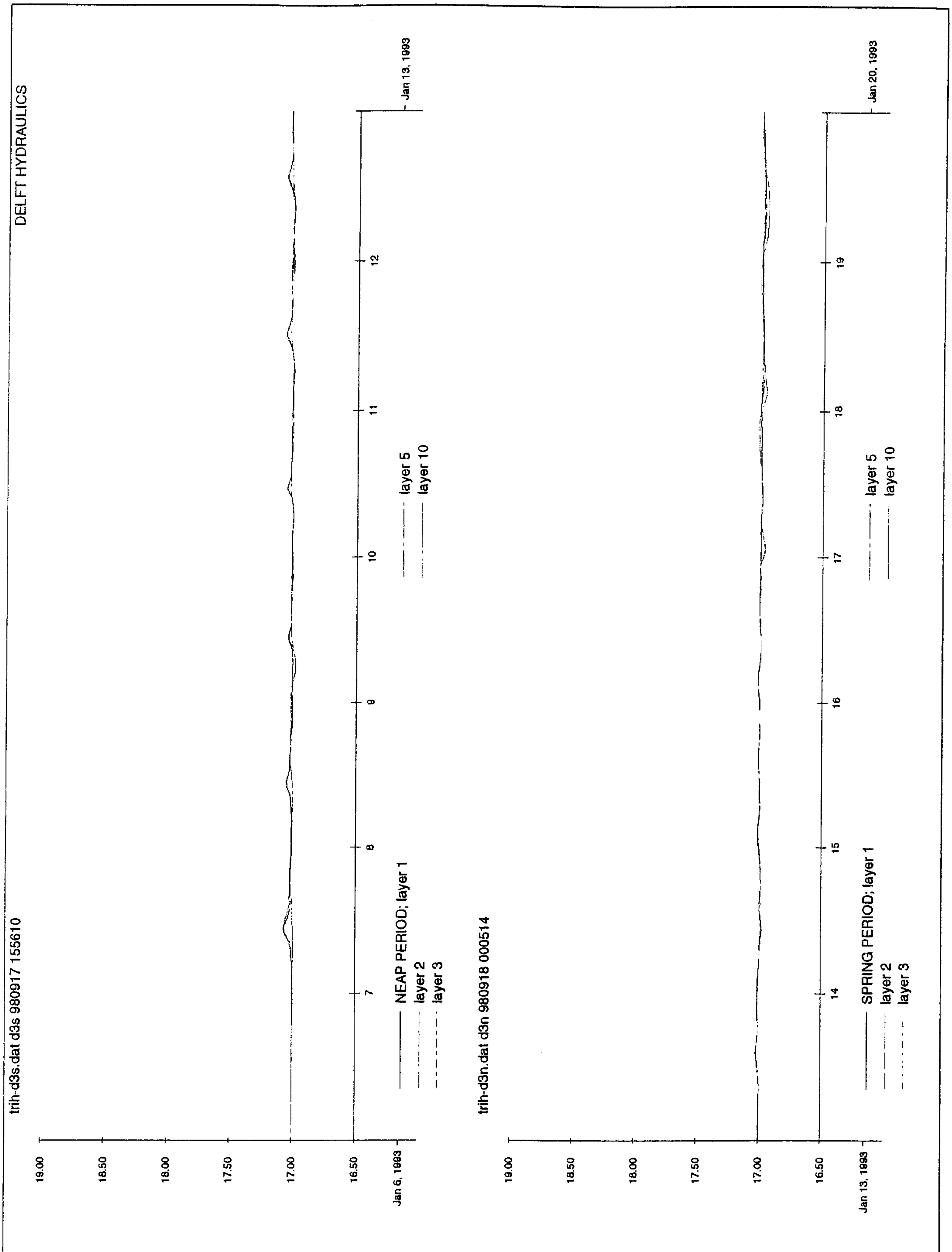
Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Lamma Island Power Outfall		1998-09-23 15:27:38
DELFT HYDRAULICS		Fig. 4.1.3



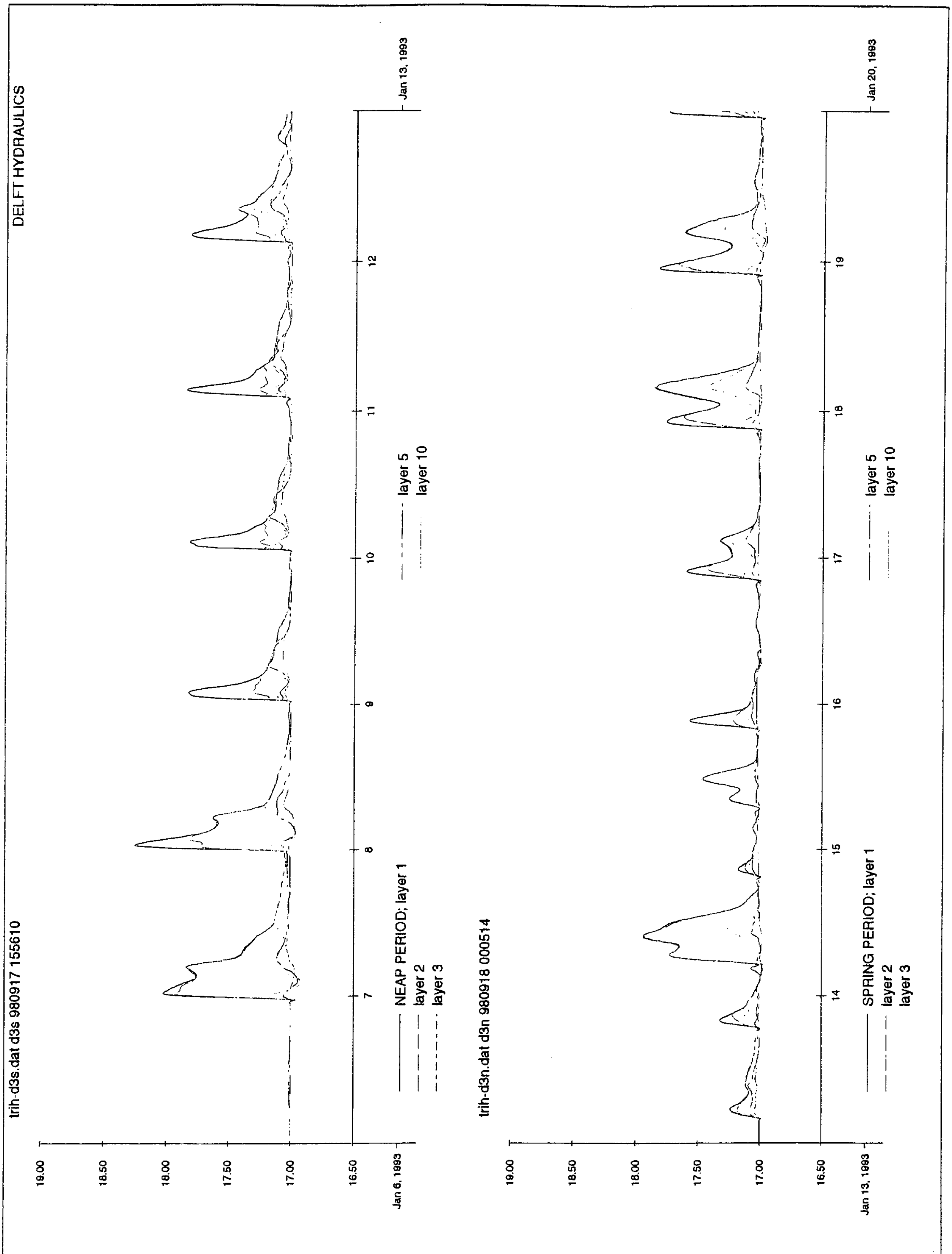
Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Lamma island Power Intake		1998-09-23 15:27:41
DELFT HYDRAULICS		Fig. 4.1.4



Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Hung Shing Ye Beach		1998-09-23 15:27:44
DELFT HYDRAULICS		Fig. 4.1.5



Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Lo So Shing Beach		1998-09-23 15:27:48
DELFT HYDRAULICS		Fig. 4.1.6

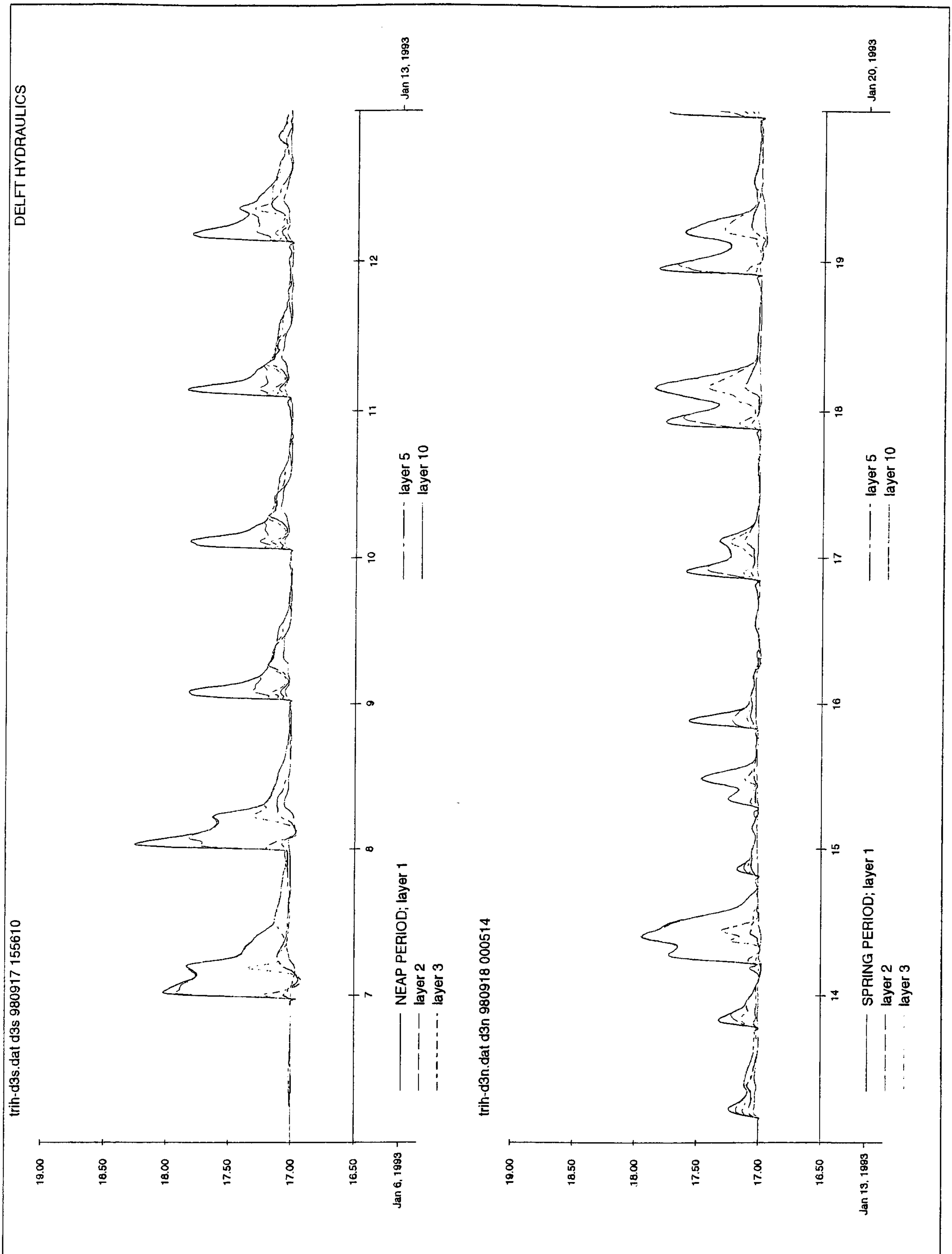


Existing Lamma Island Power Station; Scenario 1
Time series of temperature for 6-19 January 1993 (Dry season)
South Lamma Marine Park 1

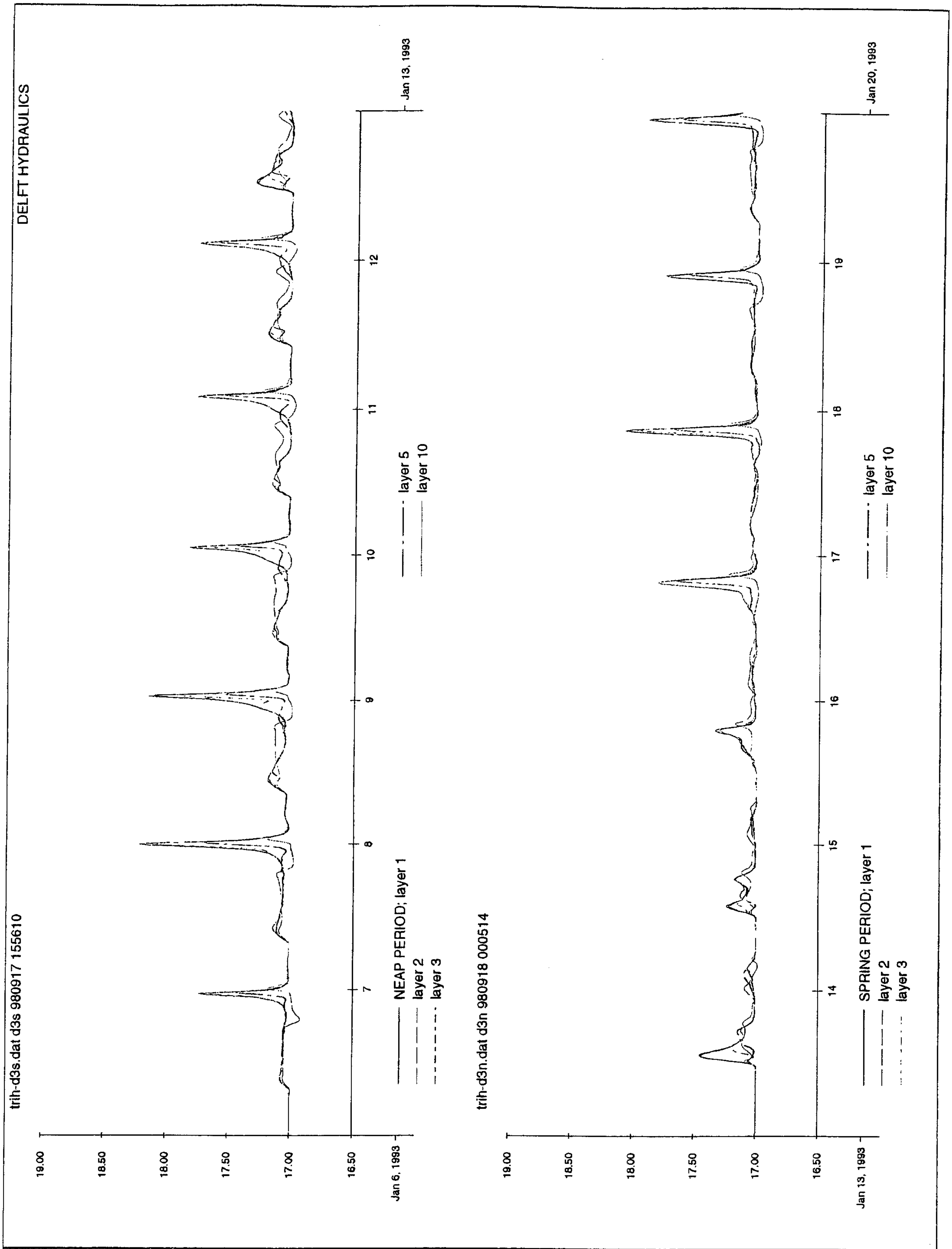
1998-09-23
15:27:50

DELFT HYDRAULICS

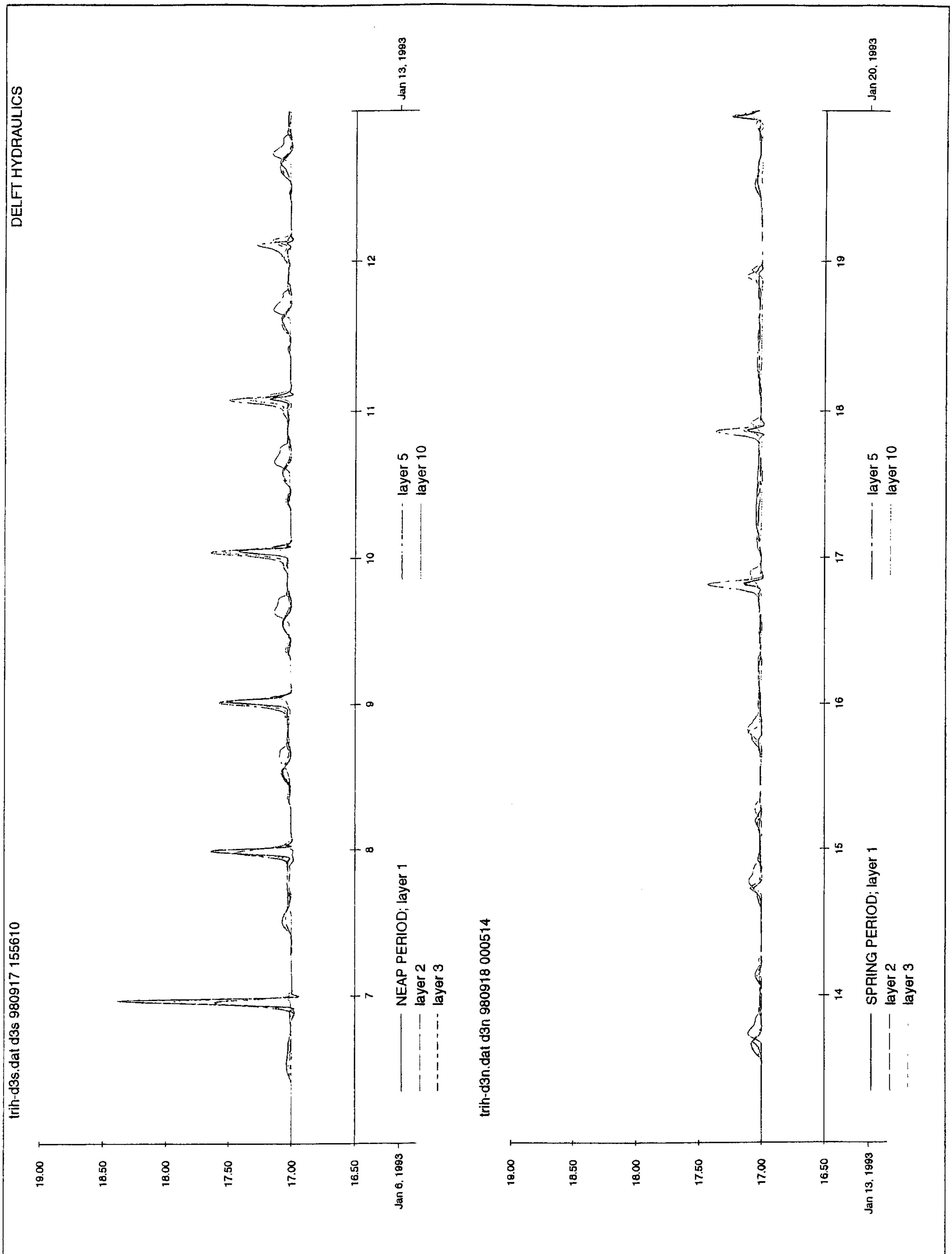
Fig. 4.1.7



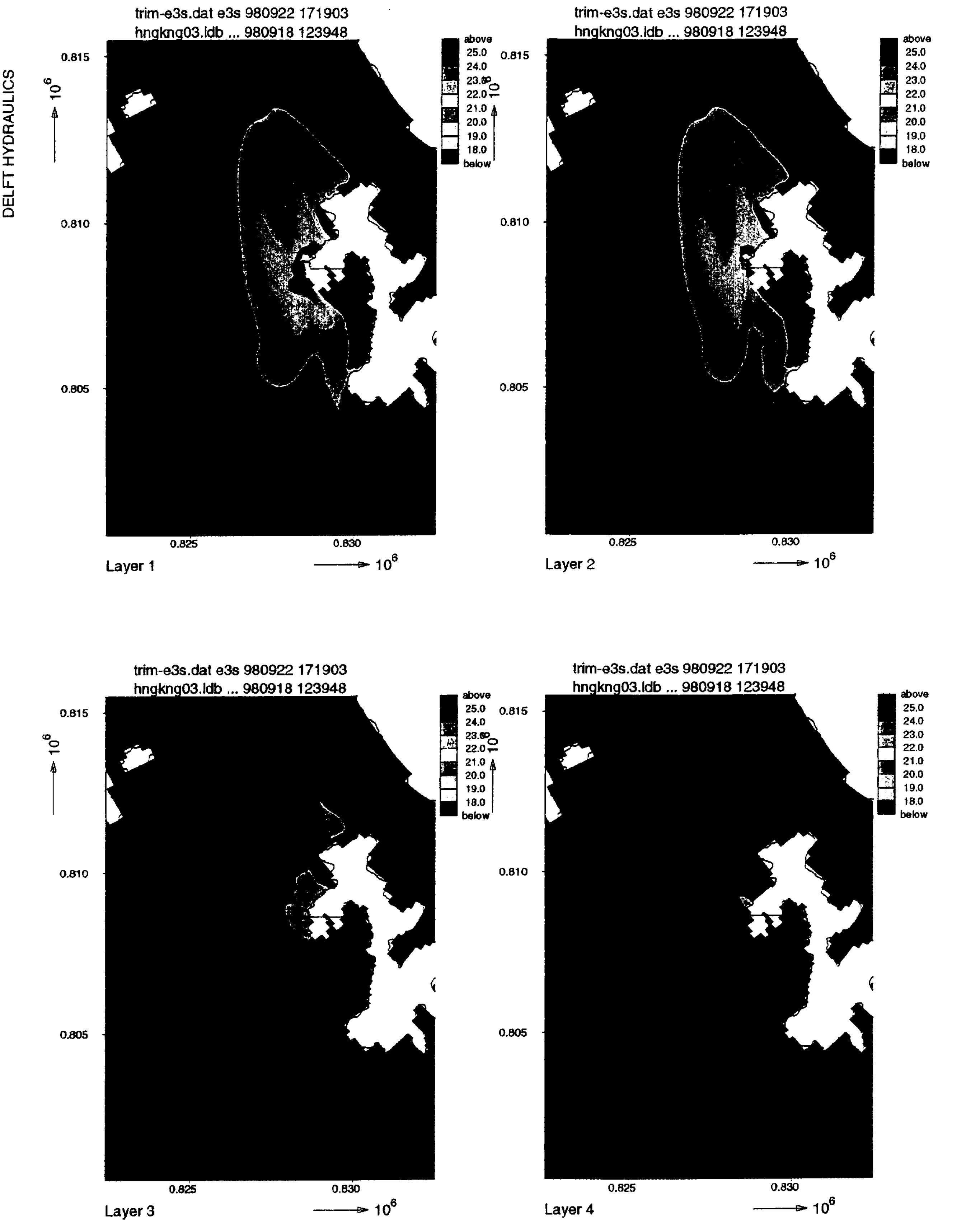
Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) South Lamma Marine Park 2		1998-09-23 15:27:54
DELFT HYDRAULICS		Fig. 4.1.8



Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Shek Kok Tsui Coral	1998-09-23 15:27:57
DELFT HYDRAULICS	Fig. 4.1.9



Existing Lamma Island Power Station; Scenario 1 Time series of temperature for 6-19 January 1993 (Dry season) Pak Kok Coral		1998-09-23 15:28:00
DELFT HYDRAULICS		Fig. 4.1.10

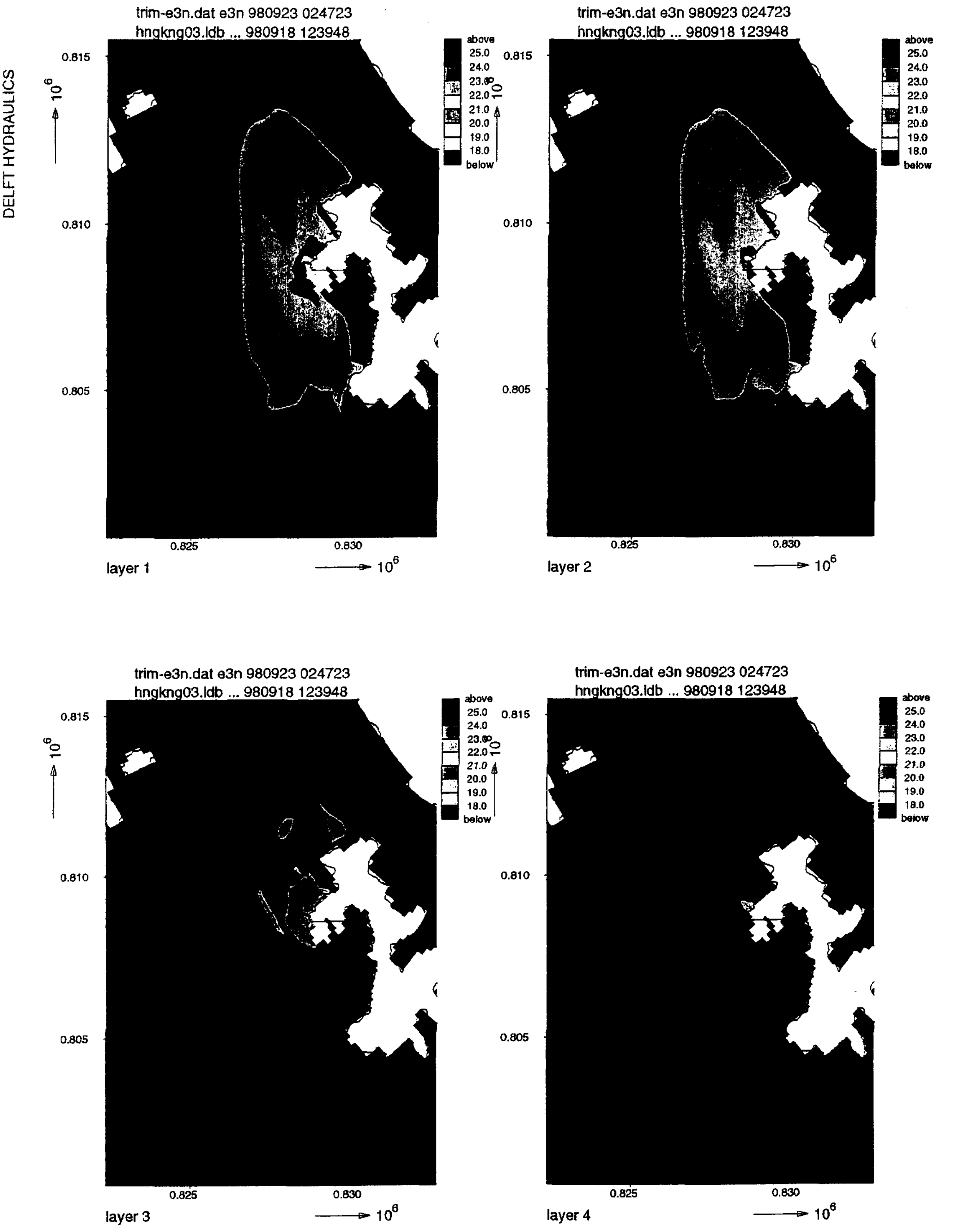


Extension Lamma Island Power Station; Scenario 2
Maximum temperature for 6-12 January 1993 (Spring tide)
Dry Season; For layers 1 to 4 (layer 1 = surface layer)

1998-09-23
13:08:26

DELFT HYDRAULICS

Fig. 4.2.1

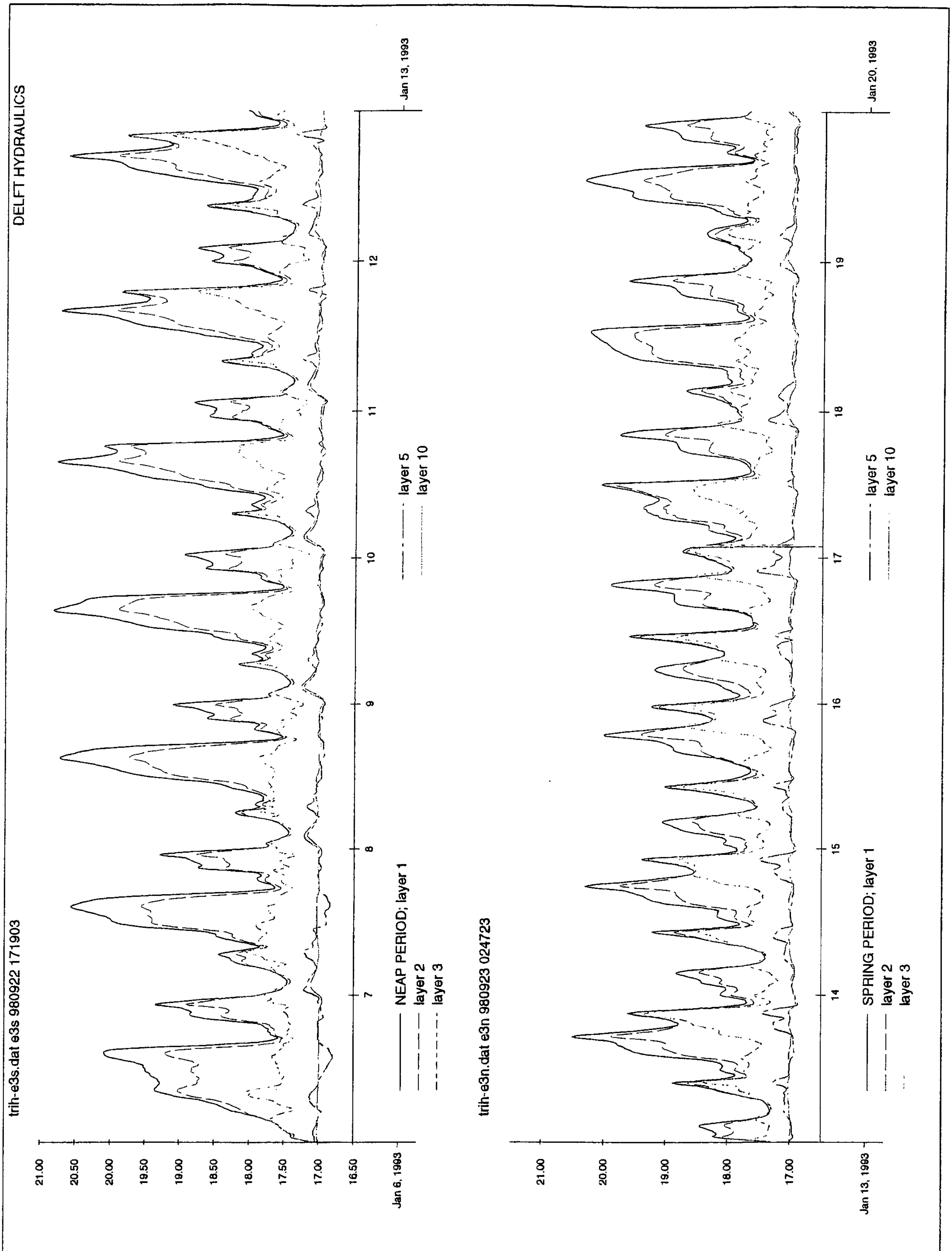


Extension Lamma Island Power Station; Scenario 2
Maximum temperature for 13-19 January 1993 (Neap tide)
Dry Season; For layers 1 to 4 (layer 1 = surface layer)

1998-09-23
13:08:31

DELFT HYDRAULICS

Fig. 4.2.2

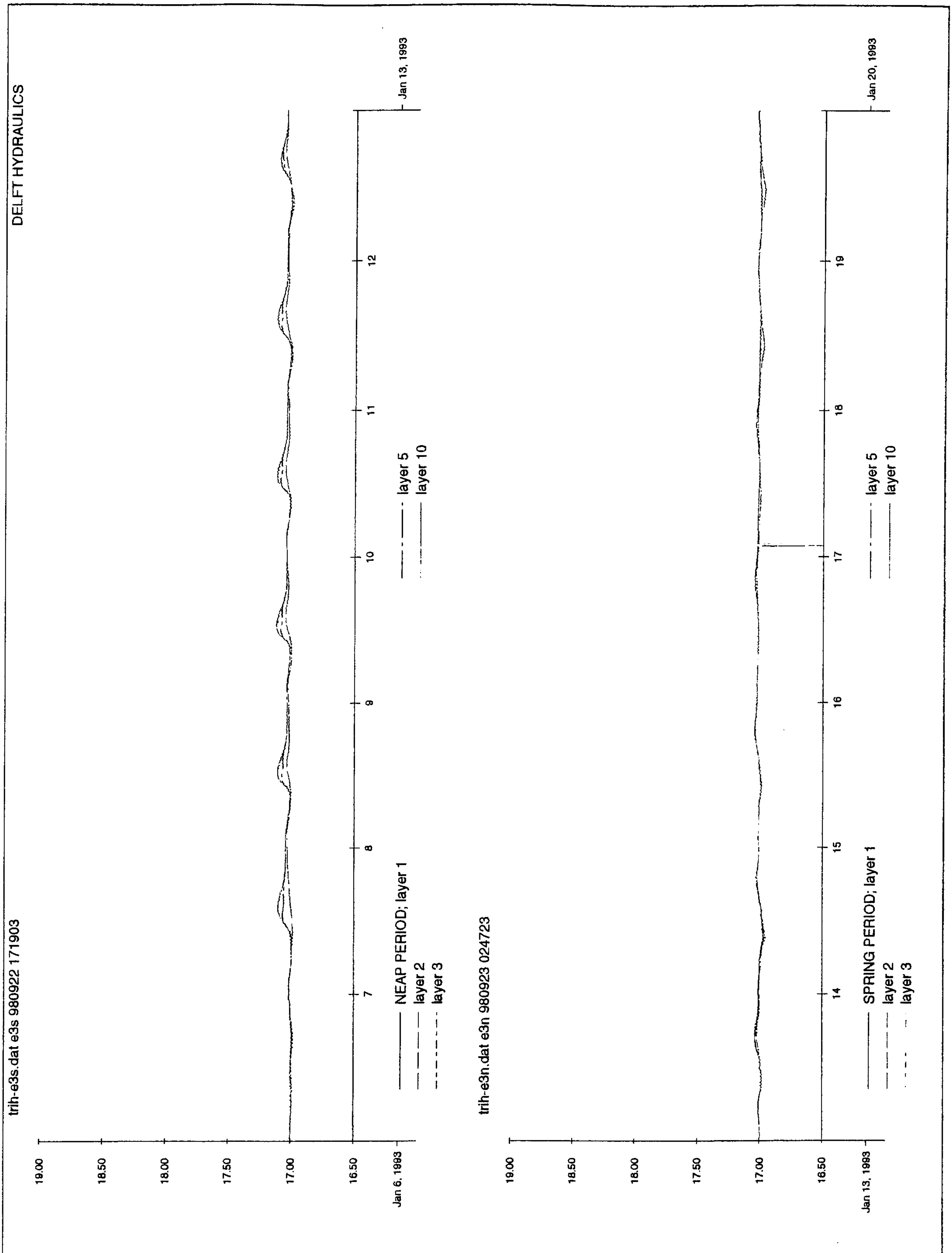


Extension Lamma Island Power Station; Scenario 2
Time series of temperature for 6-19 January 1993 (Dry season)
Outfall Lamma Power extension

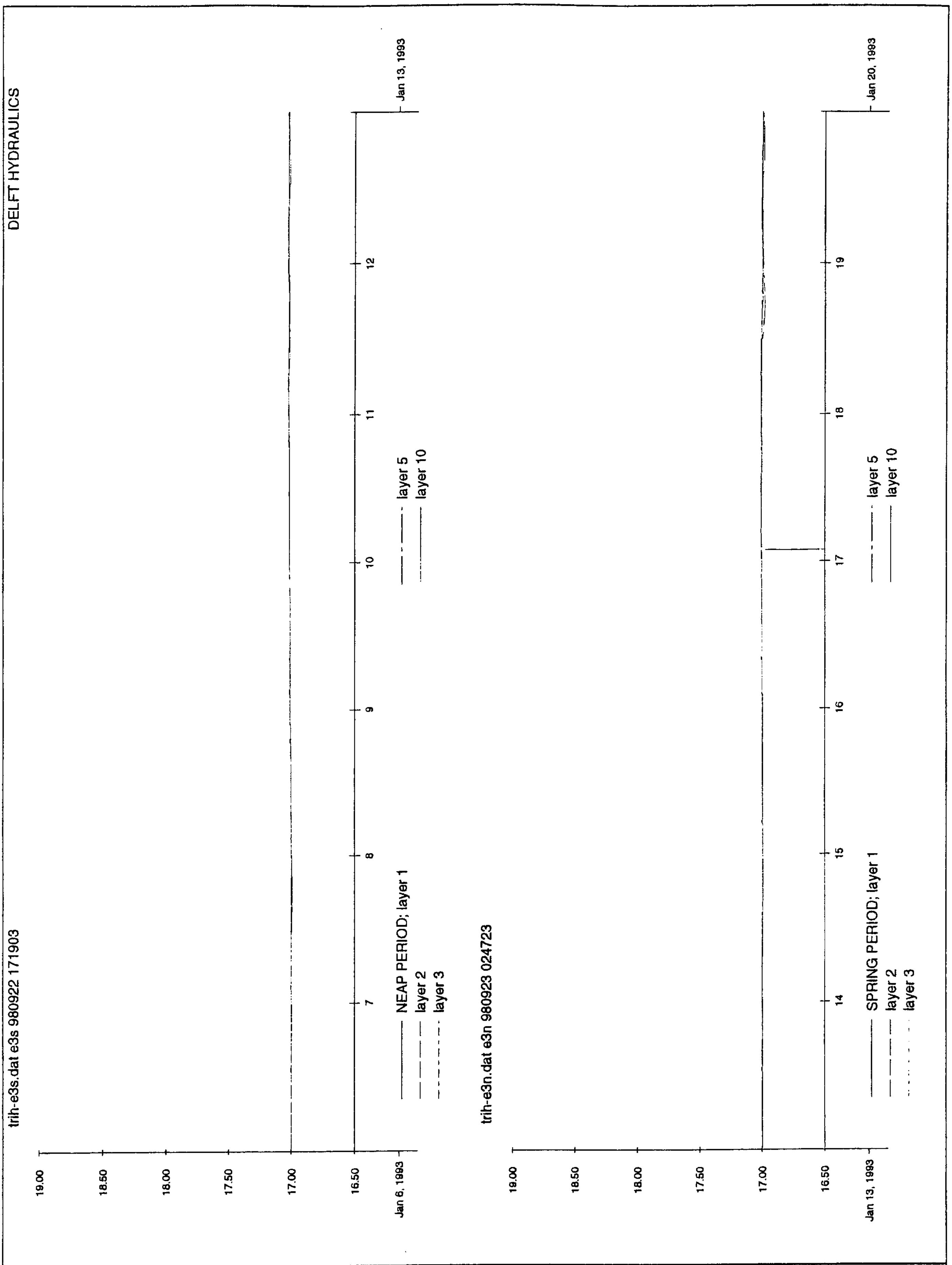
1998-09-23
16:00:10

DELFT HYDRAULICS

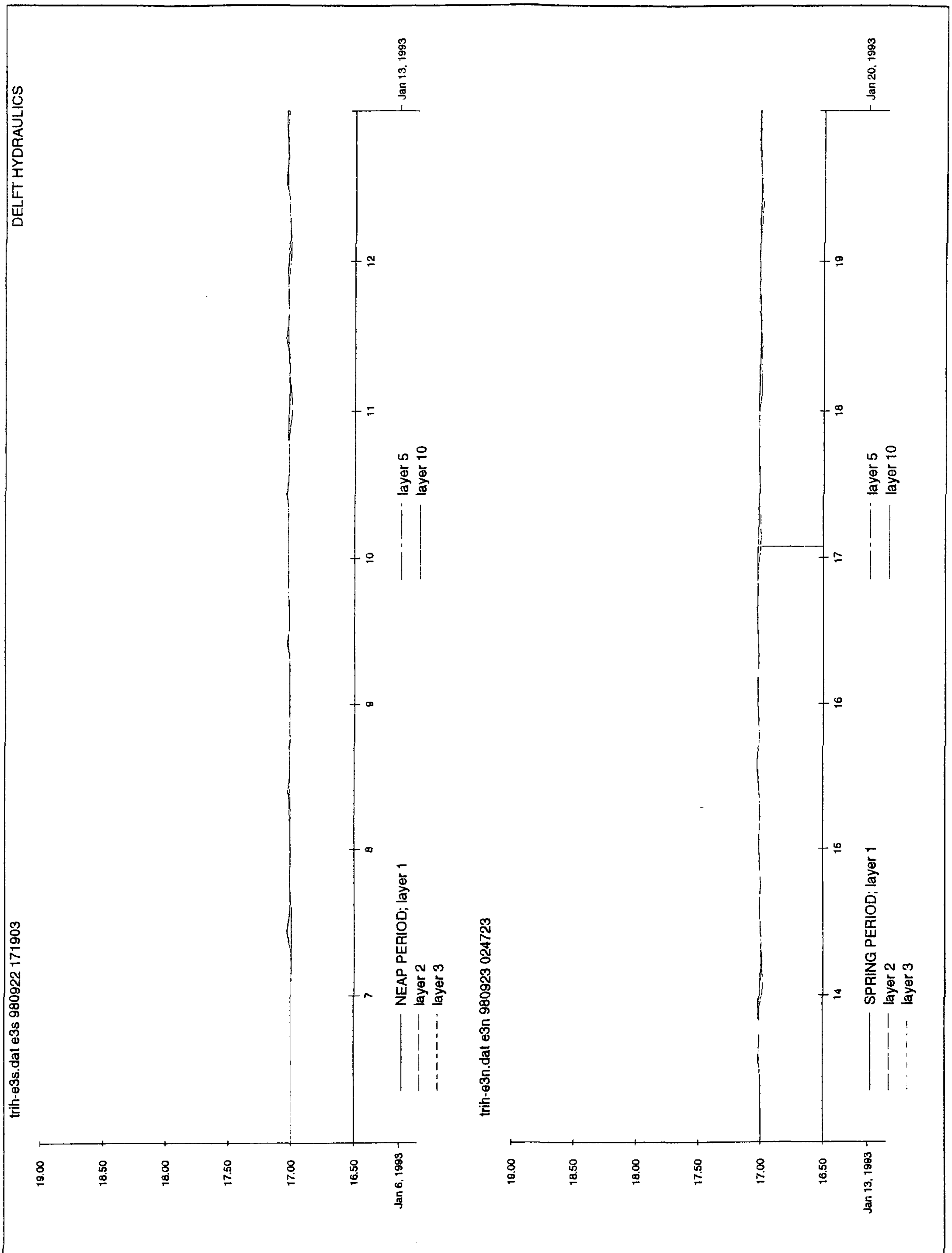
Fig. 4.2.3



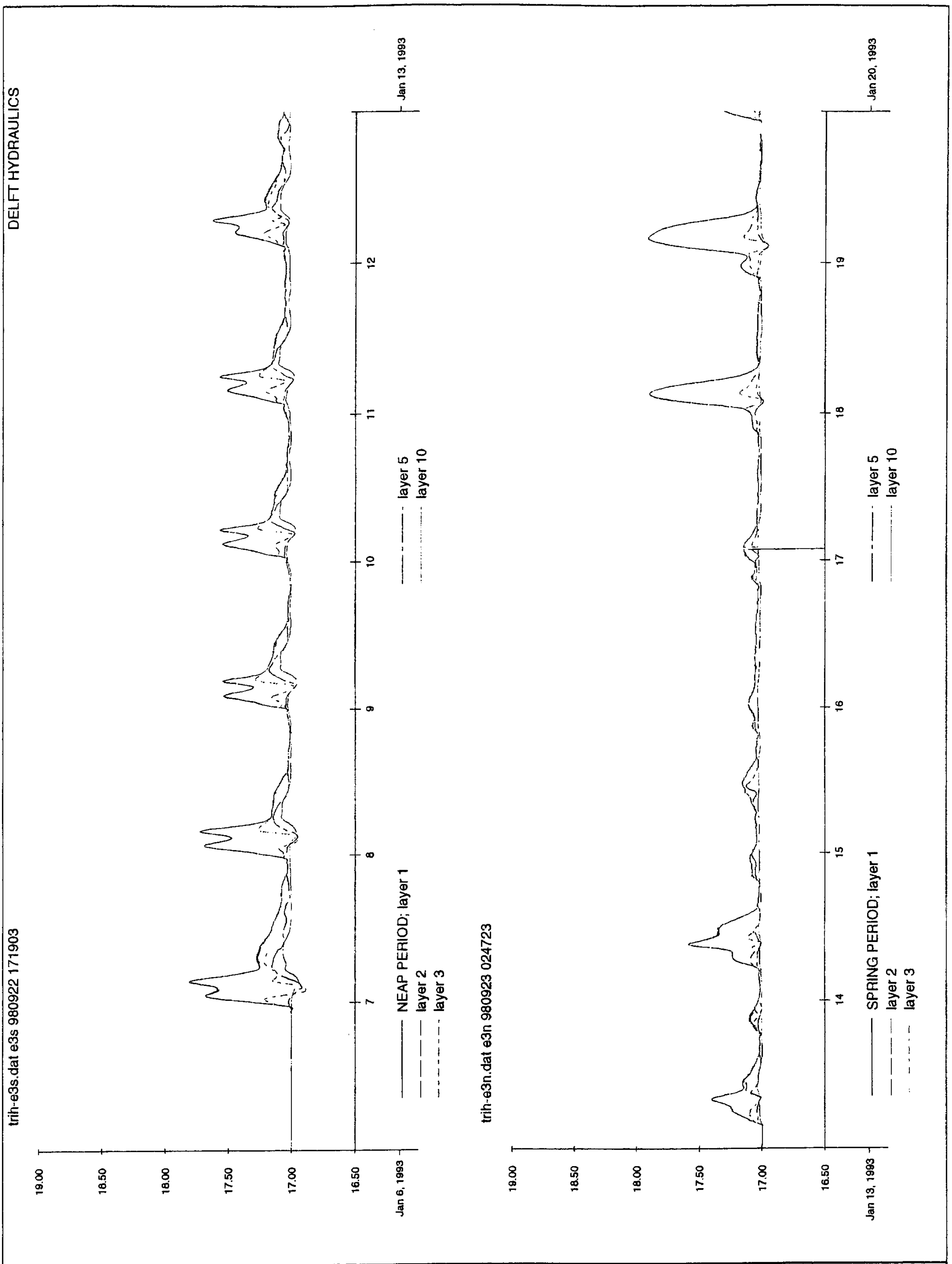
Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) Lamma island Power Intake		1998-09-23 15:31:20
DELFT HYDRAULICS		Fig. 4.2.4



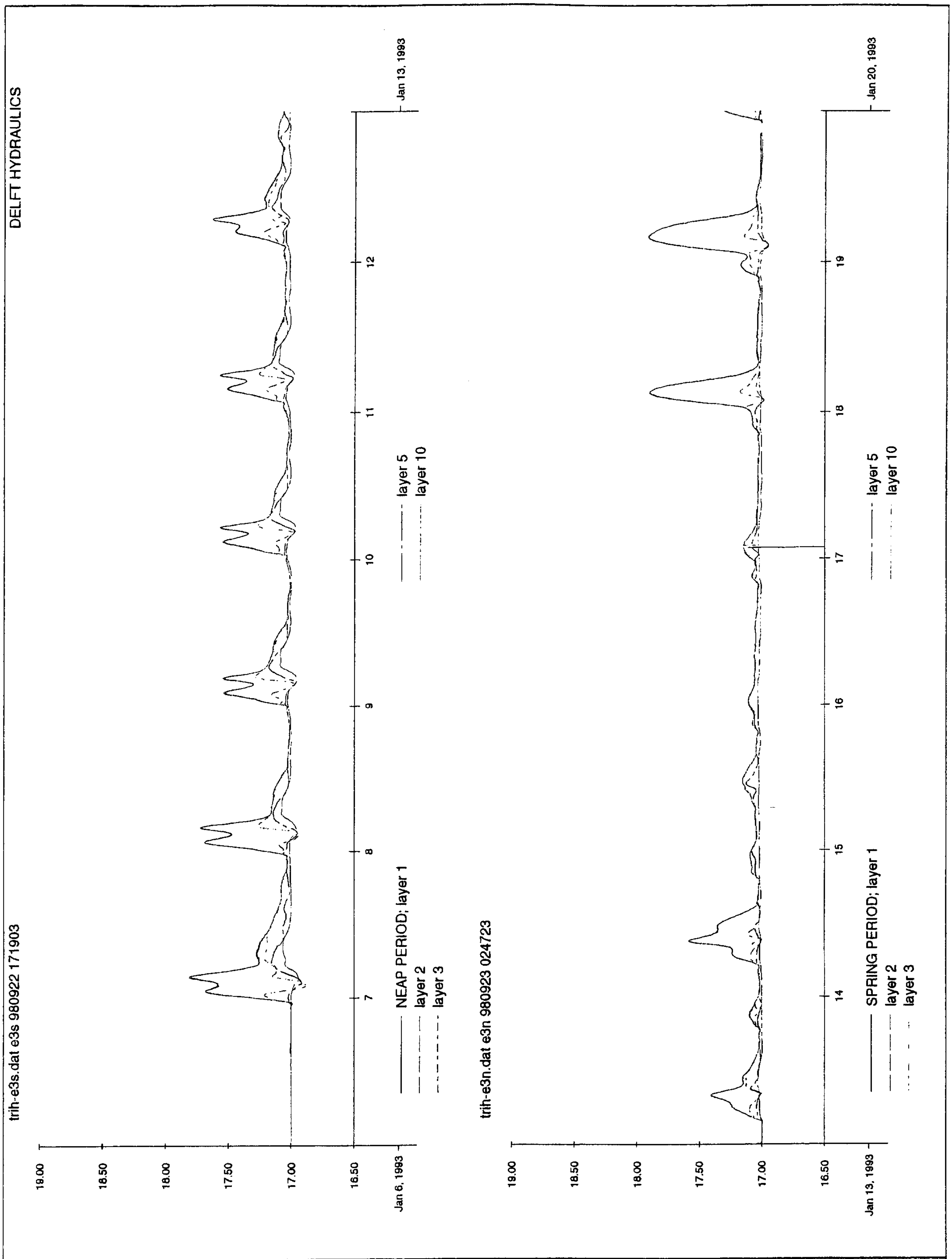
Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) Hung Shing Ye Beach	1998-09-23 15:31:23
DELFT HYDRAULICS	Fig. 4.2.5



Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) Lo So Shing Beach		1998-09-23 15:31:27
DELFT HYDRAULICS		Fig. 4.2.6



Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) South Lamma Marine Park 1	1998-09-23 15:31:32
DELFT HYDRAULICS	Fig. 4.2.7



Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) South Lamma Marine Park 2		1998-09-23 15:31:36
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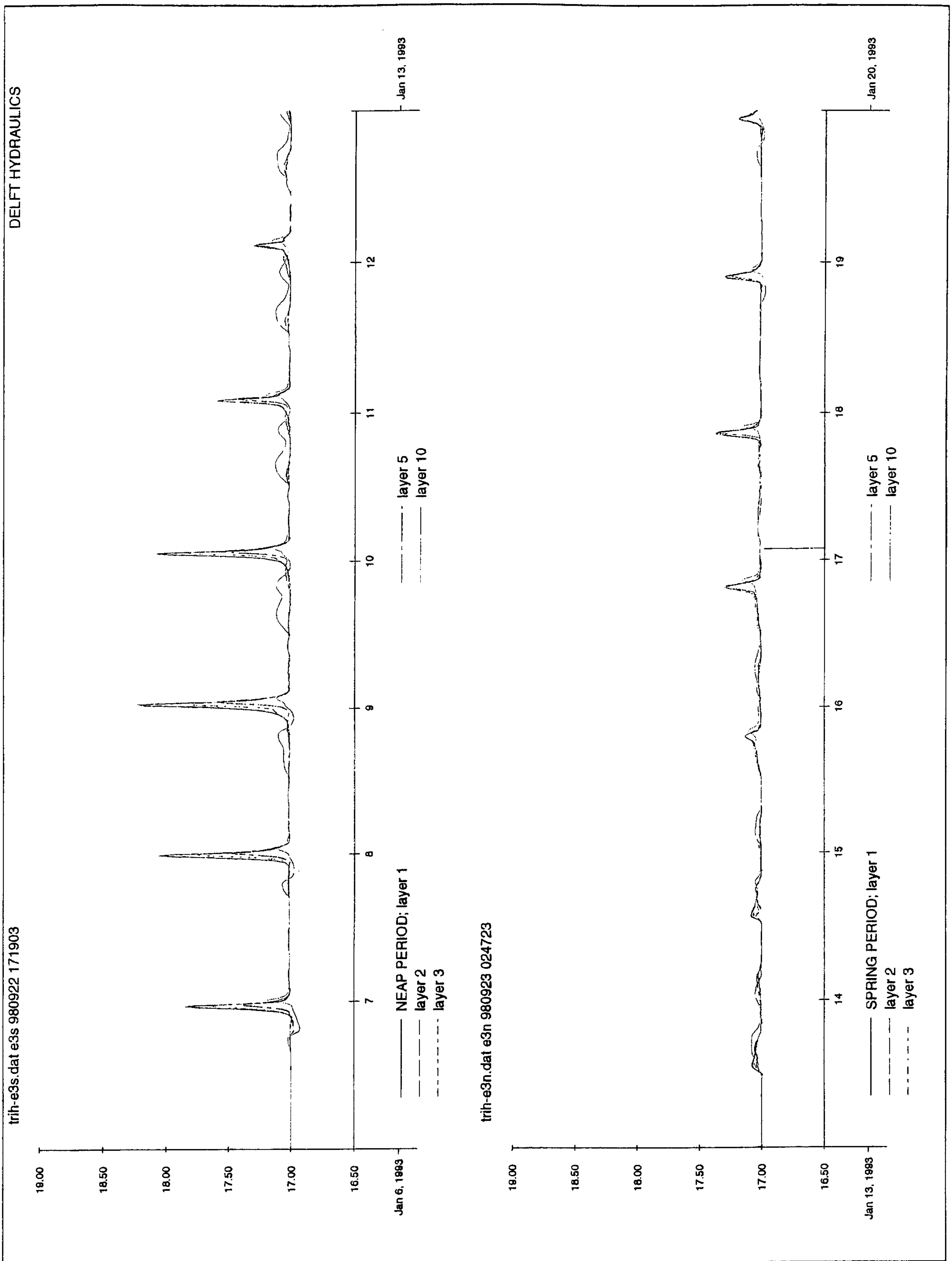

Extension Lamma Island Power Station; Scenario 2 Time series of temperature for 6-19 January 1993 (Dry season) Shek Kok Tsui Coral		1998-09-23 15:31:40
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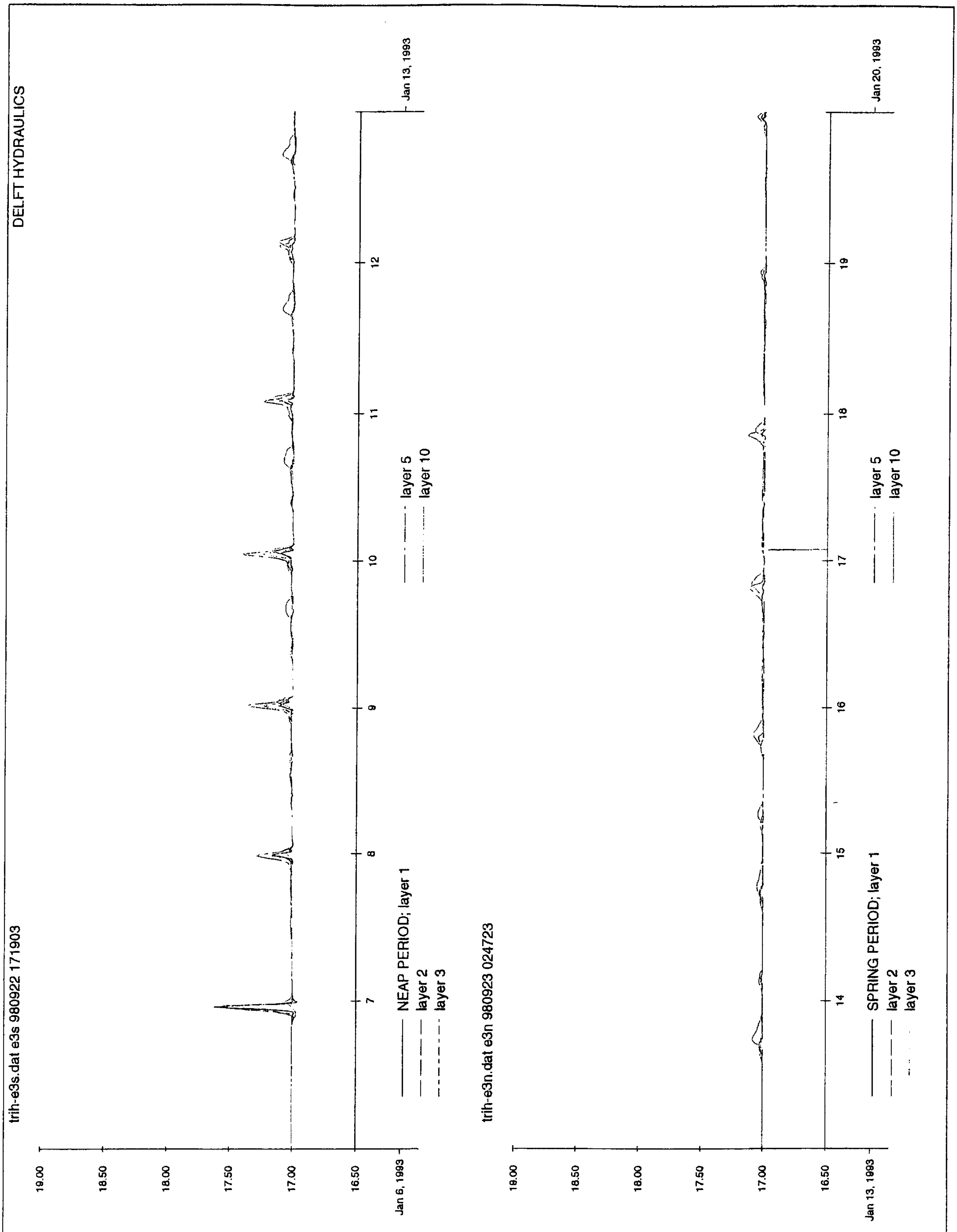
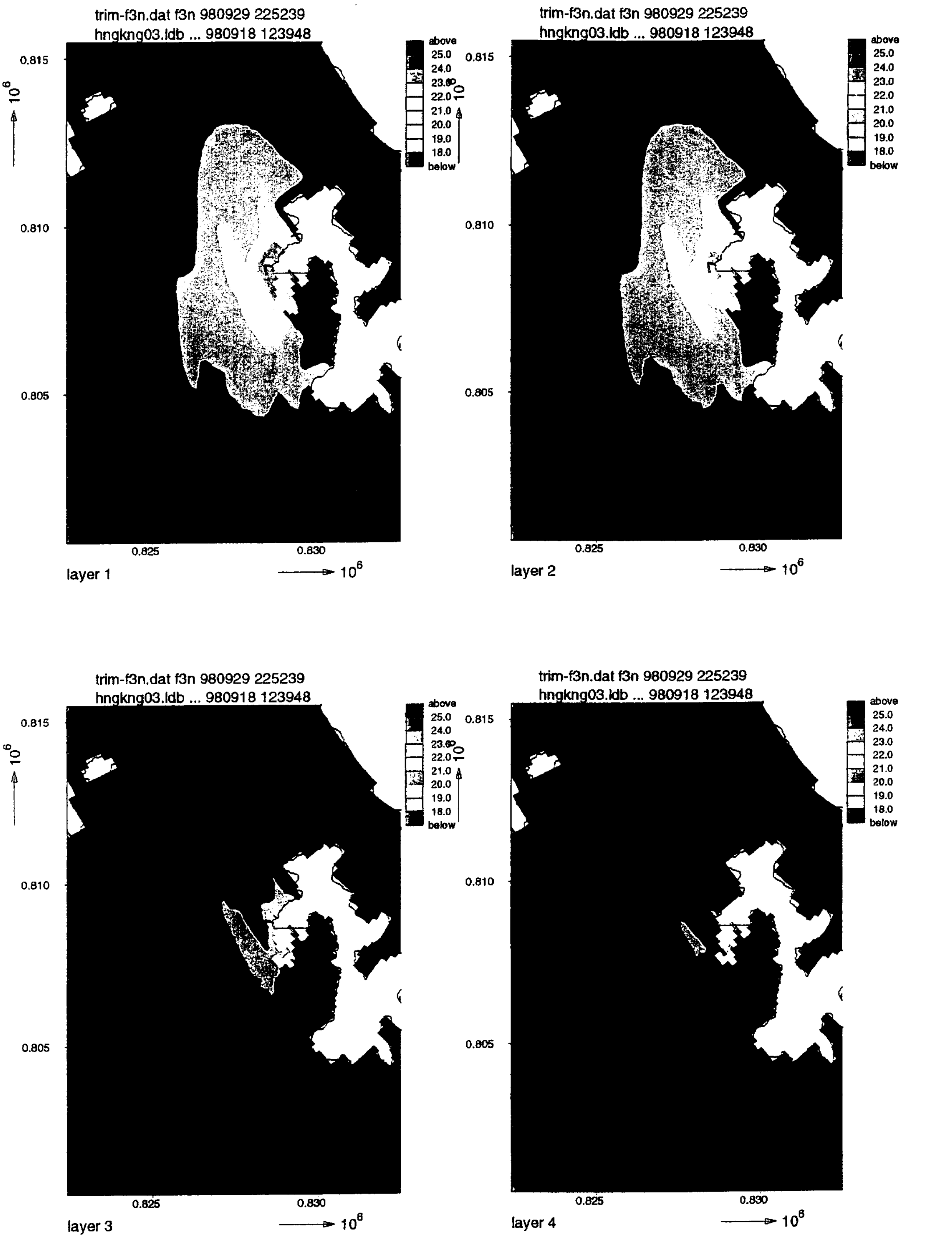


Extension Lamma Island Power Station; Scenario 2
Time series of temperature for 6-19 January 1993 (Dry season)
Pak Kok Coral

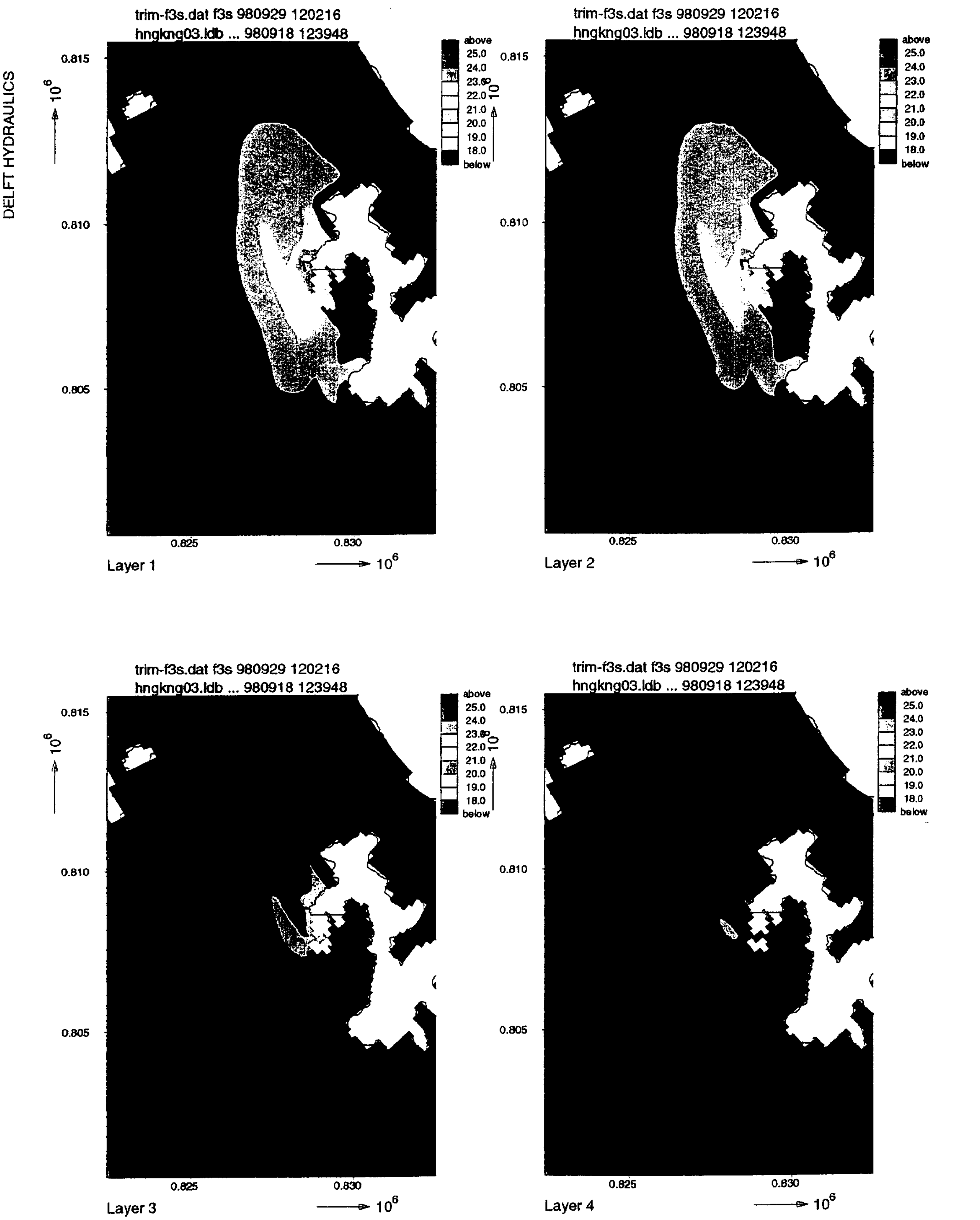
1998-09-23
15:31:44

DELFT HYDRAULICS

Fig. 4.2.10



Power Station + WEIF extension; Scenario 3 Maximum temperature for 13-19 January 1993 (Neap tide) Dry Season; For layers 1 to 4 (layer 1 = surface layer)		1998-10-01 09:15:38
DELFT HYDRAULICS		Fig. 4.3.1

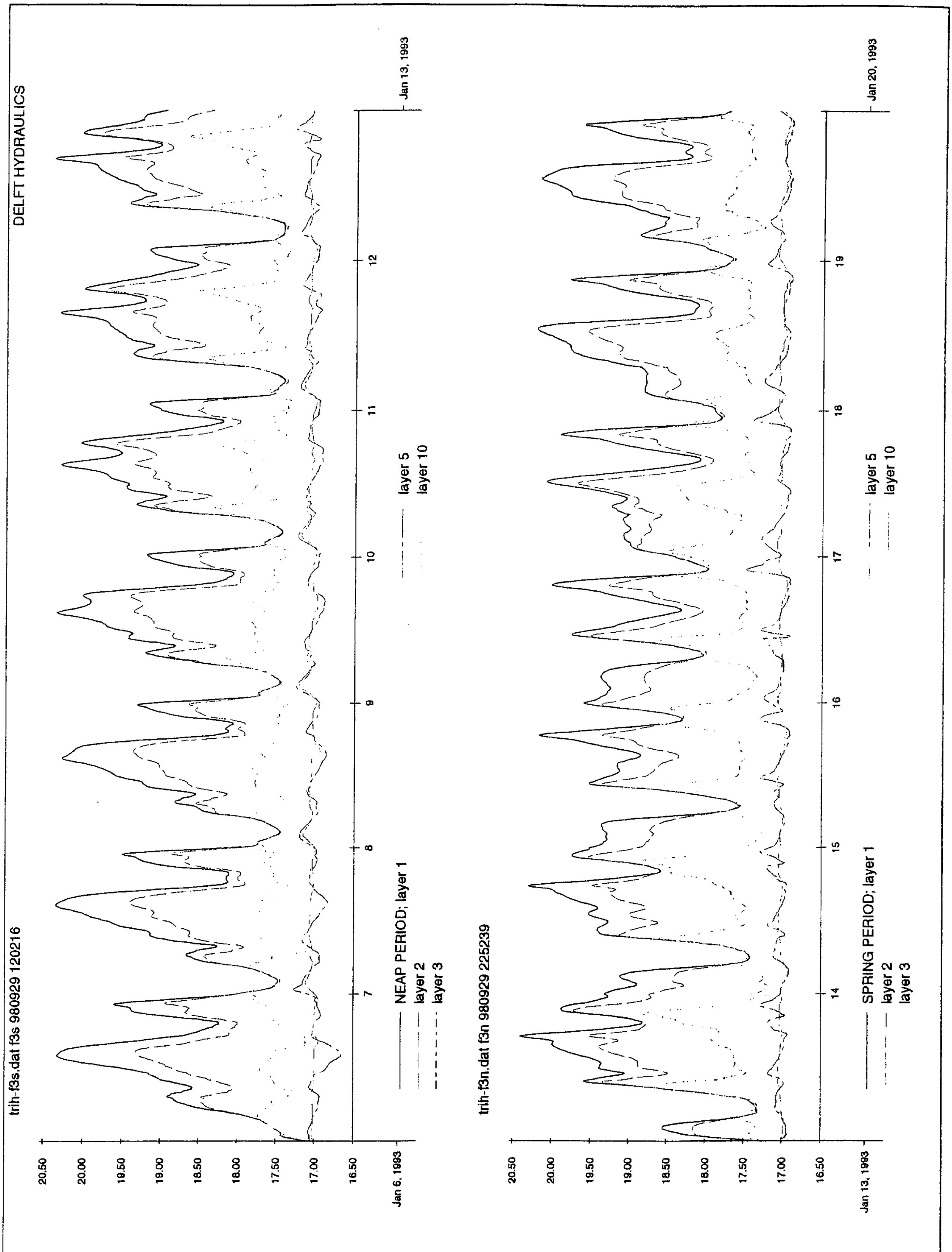


Power Station + WEIF extension; Scenario 3
Maximum temperature for 6-12 January 1993 (Spring tide)
Dry Season; For layers 1 to 4 (layer 1 = surface layer)

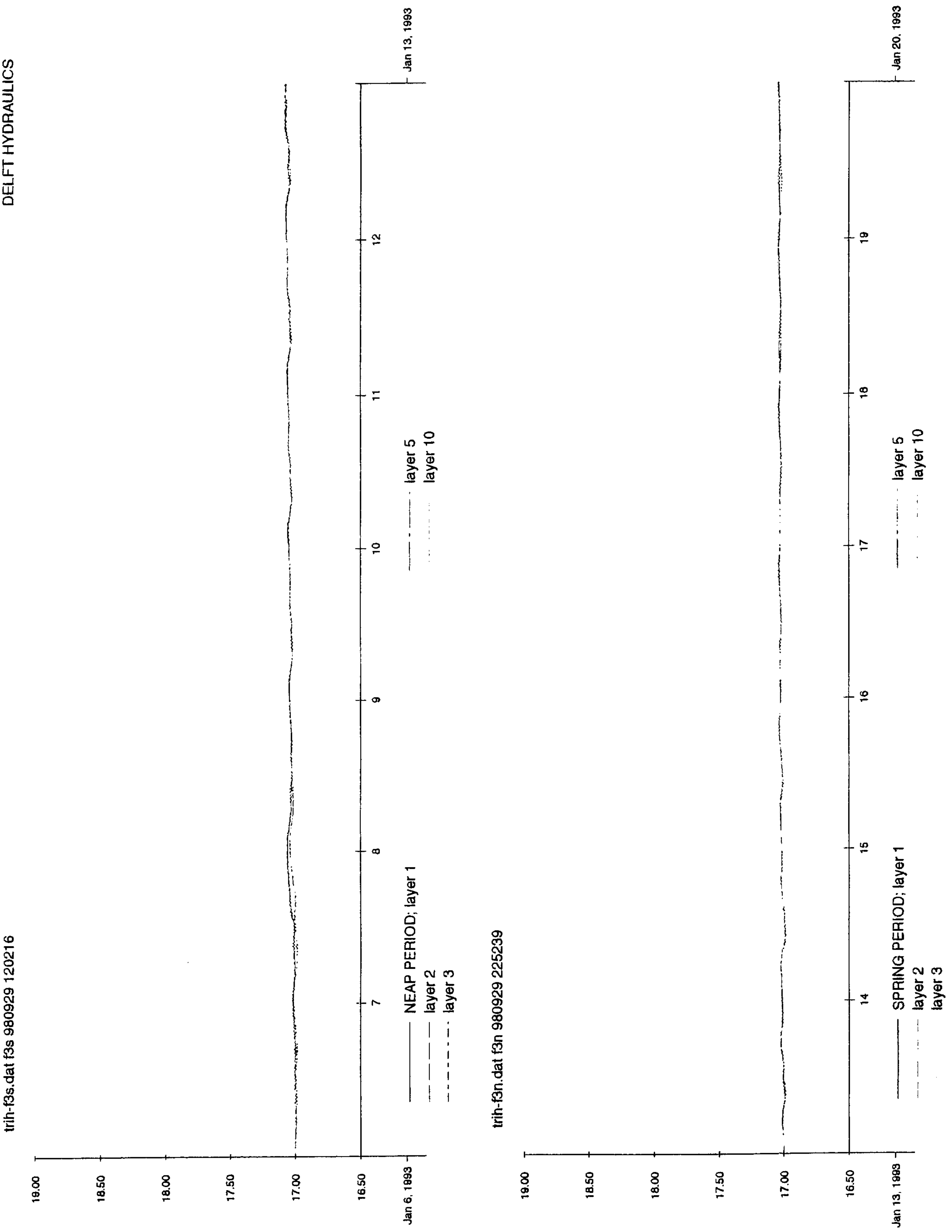
1998-10-01
09:15:35

DELFT HYDRAULICS

Fig. 4.3.2



Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) Outfall Lamma Power extension		1998-10-01 09:33:06
DELFT HYDRAULICS		Fig. 4.3.3



Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) Lamma island Power Intake		1998-10-01 09:33:08
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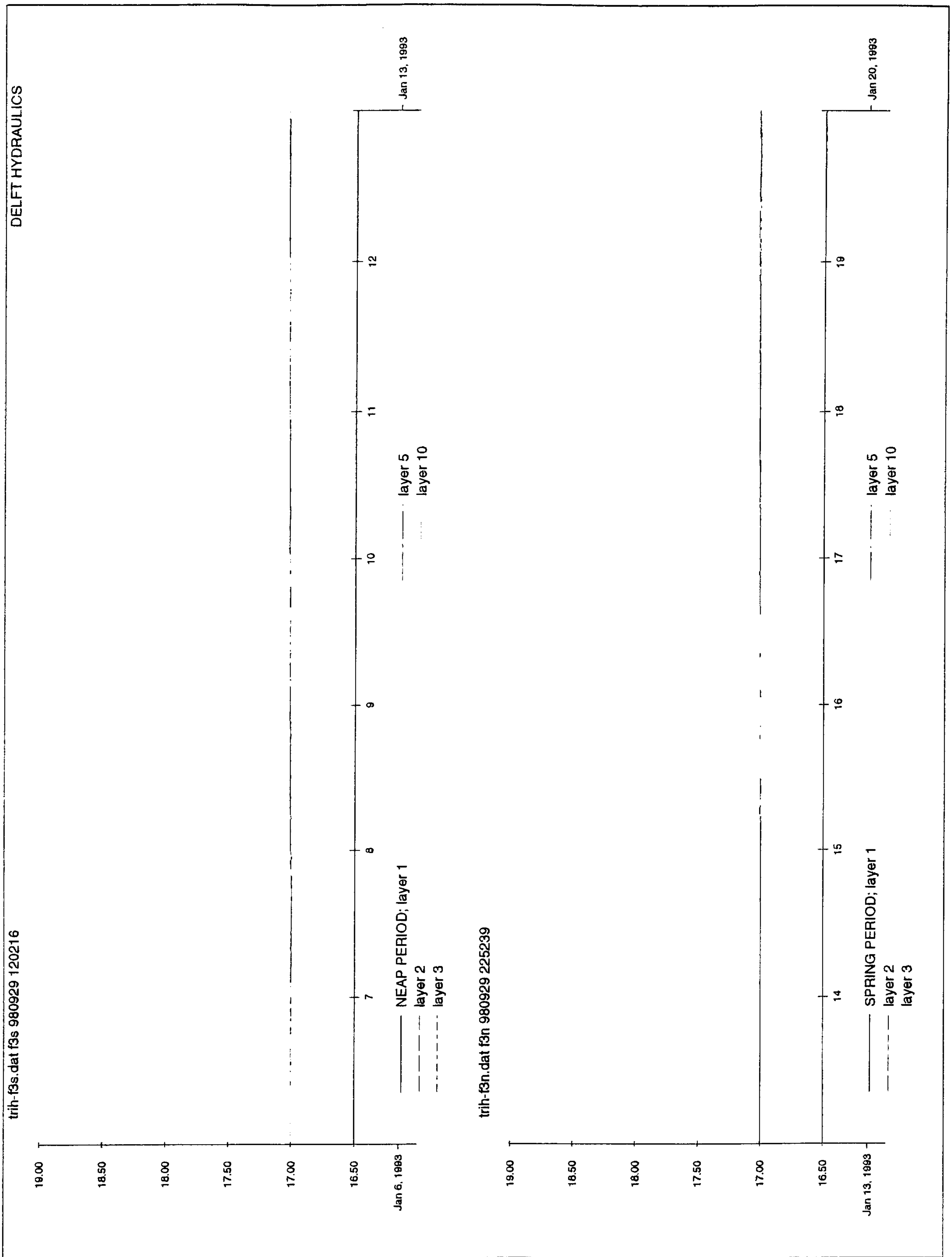
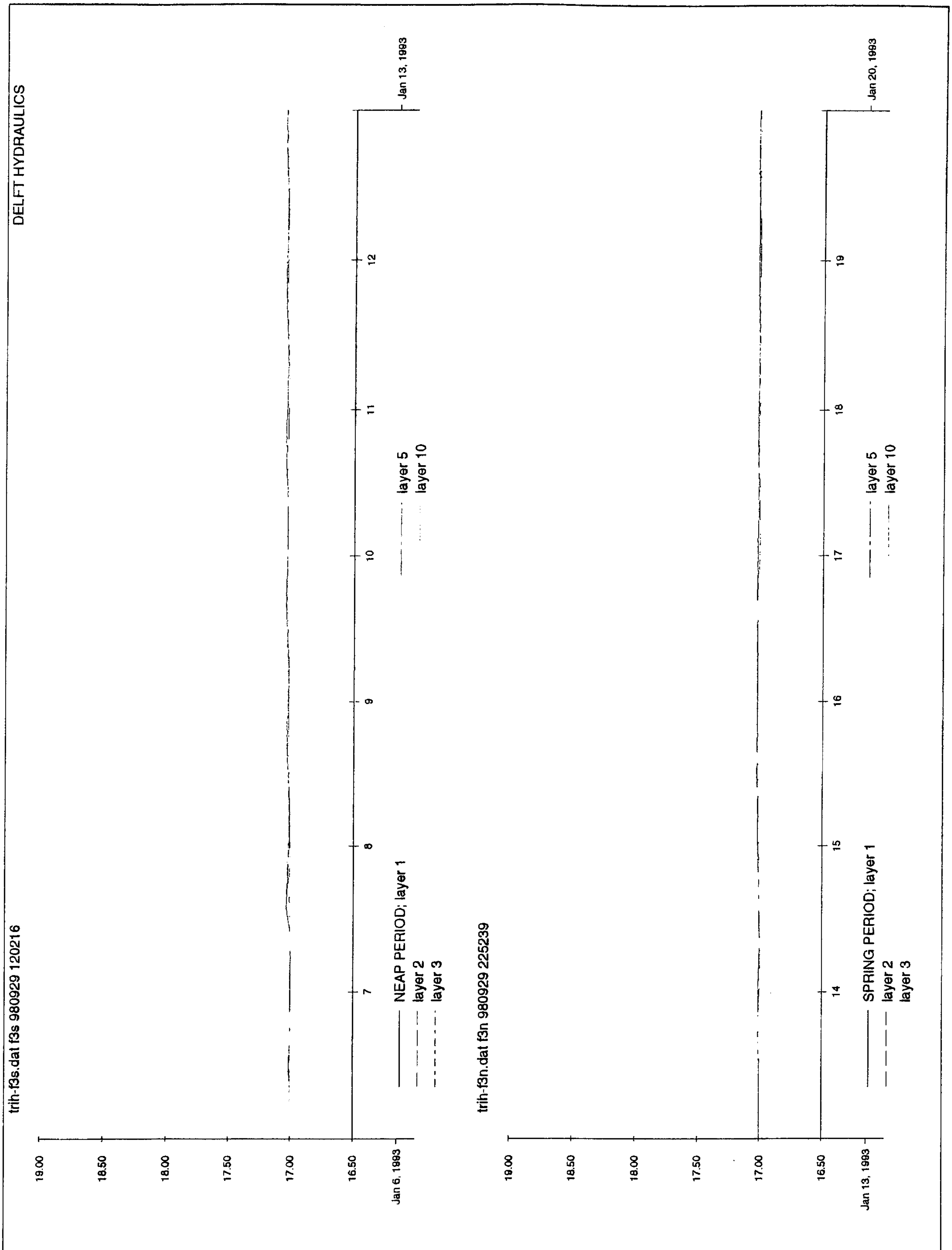
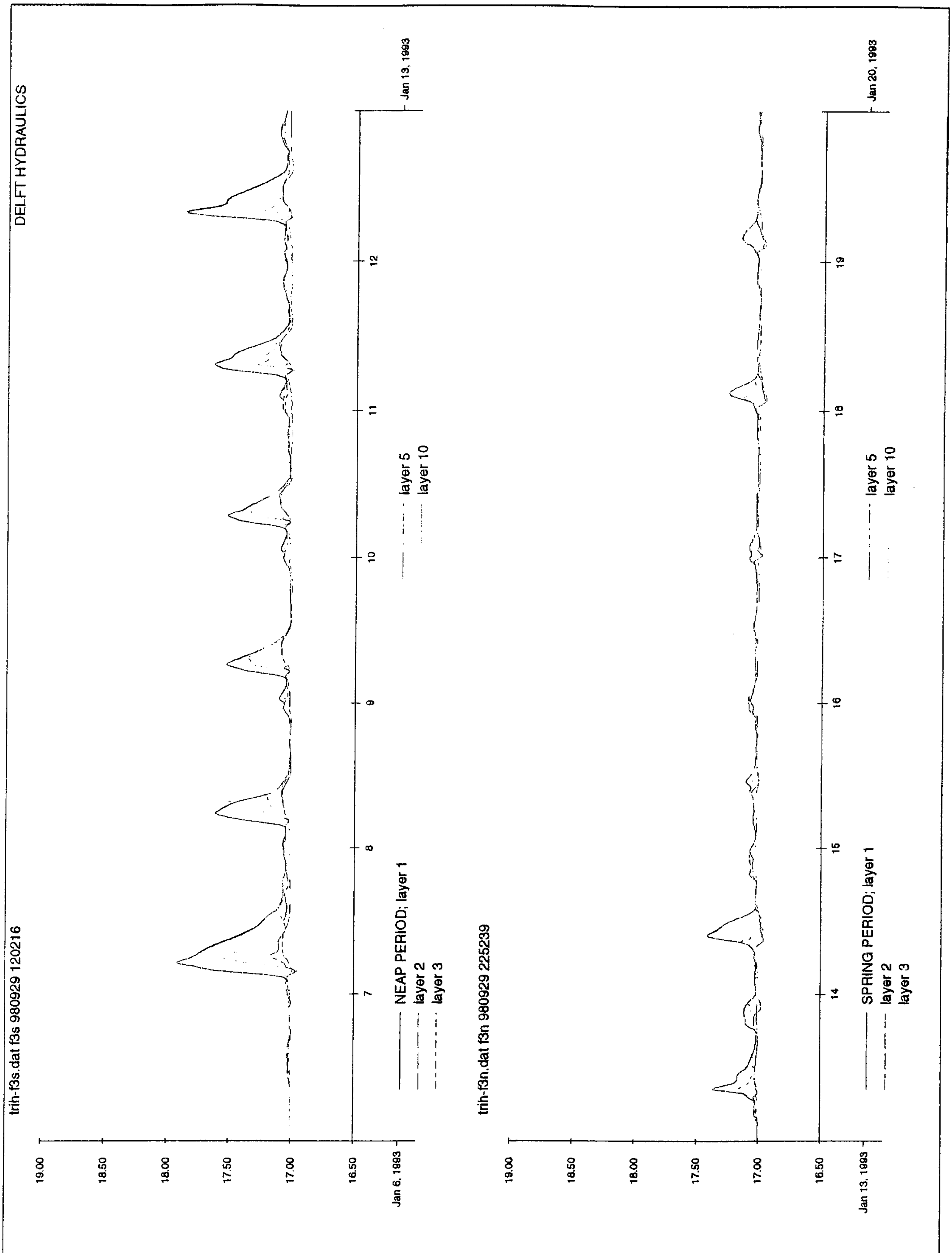


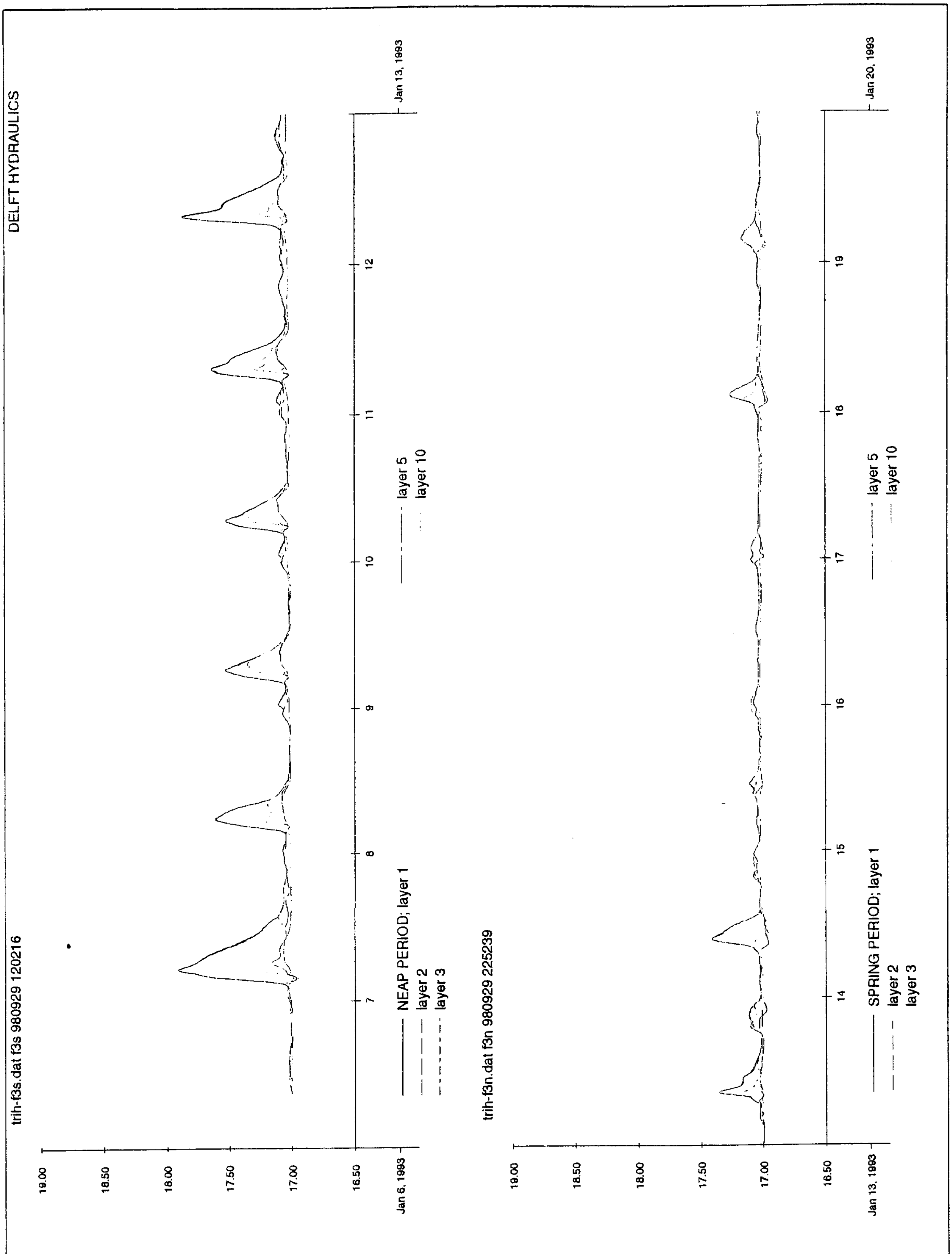
Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) Hung Shing Ye Beach		1998-10-01 09:33:10
DELFT HYDRAULICS		Fig. 4.3.5



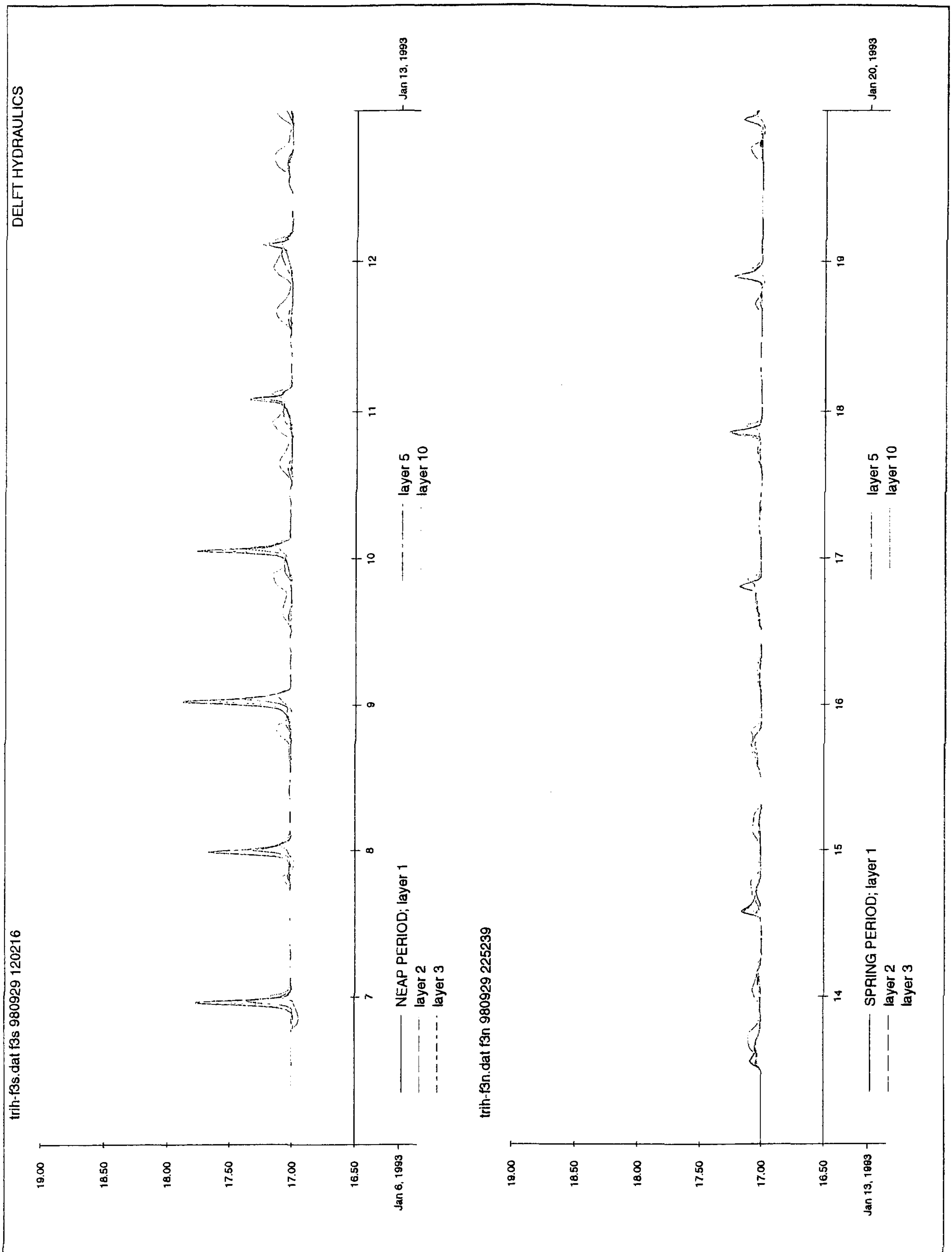
Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) Lo So Shing Beach		1998-10-01 09:33:12
DELFT HYDRAULICS		Fig. 4.3.6



Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) South Lamma Marine Park 1		1998-10-01 09:33:15
DELFT HYDRAULICS		Fig. 4.3.7



Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) South Lamma Marine Park 2		1998-10-01 09:33:17
DELFT HYDRAULICS		Fig. 4.3.8

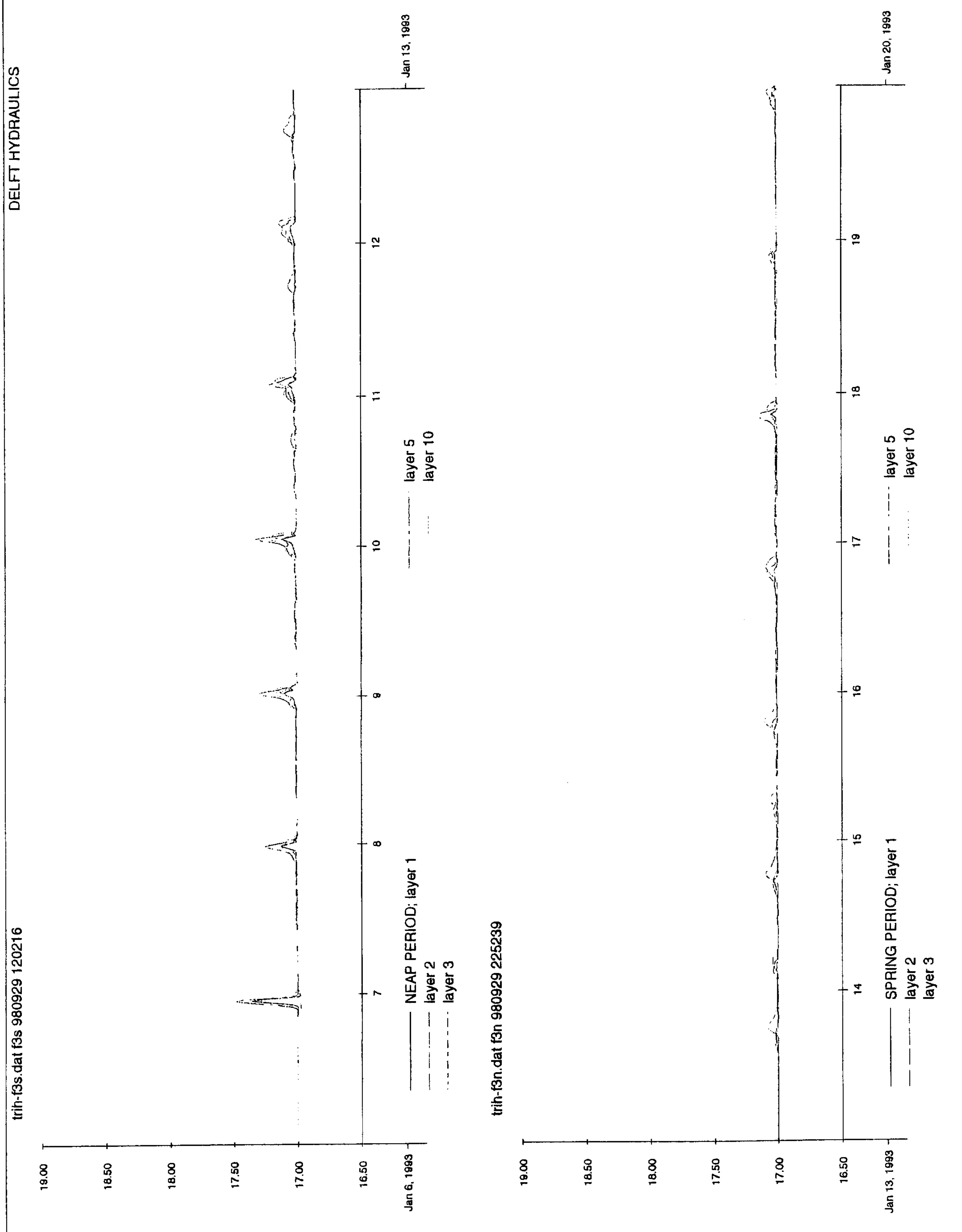


Power Station + WEIF extension; Scenario 3
Time series of temperature for 6-19 January 1993 (Dry season)
Shek Kok Tsui Coral

	1998-10-01 09:33:19

DELFT HYDRAULICS

Fig. 4.3.9



Power Station + WEIF extension; Scenario 3 Time series of temperature for 6-19 January 1993 (Dry season) Pak Kok Coral		1998-10-01 09:33:21
DELFT HYDRAULICS		Fig. 4.3.10

Annex B5-5

Results of the Chlorine Dispersion Modelling

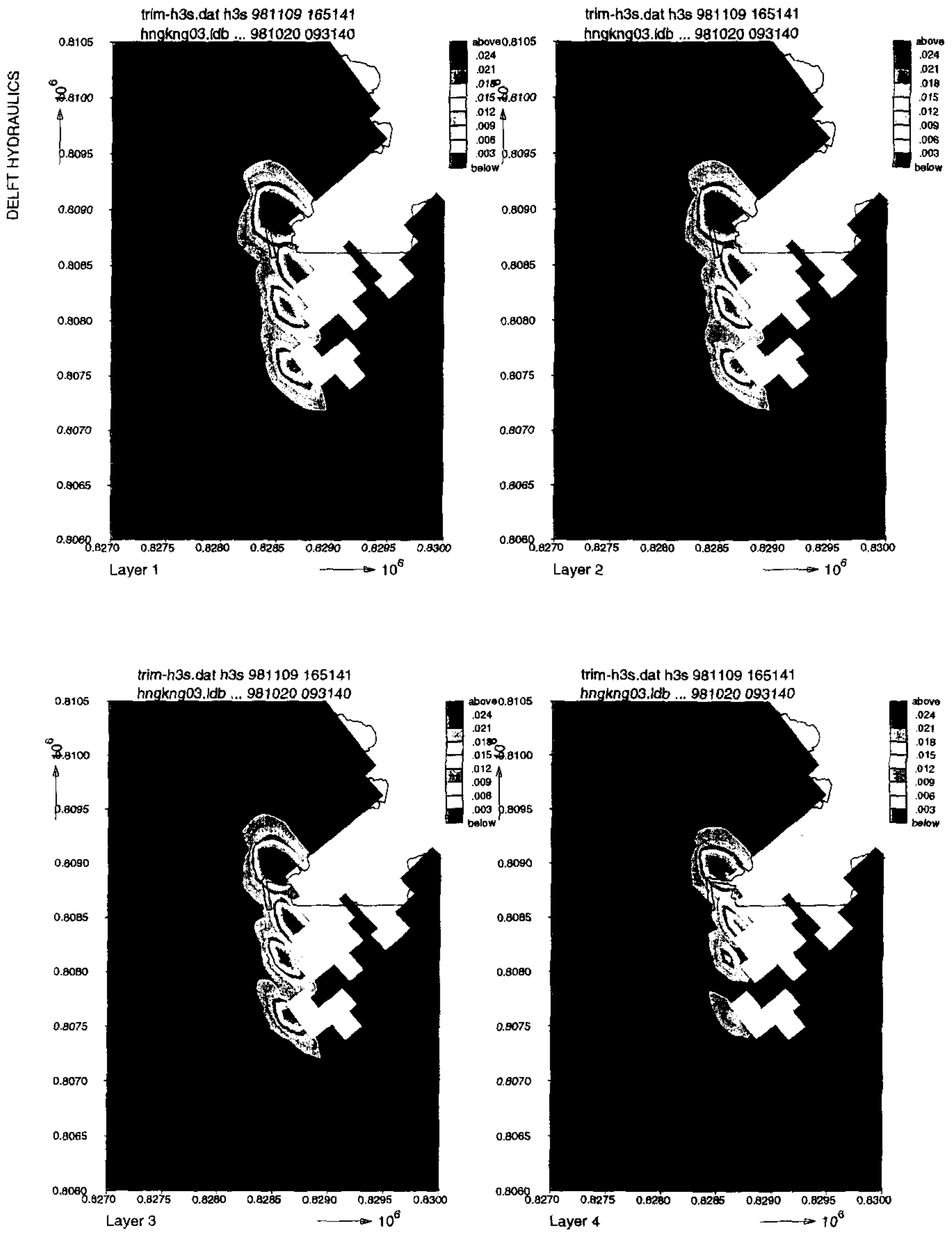


FIGURE 1

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 6-12 JANUARY 1993 (SPRING TIDE)
DRY SEASON; LAYERS 1 TO 4; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

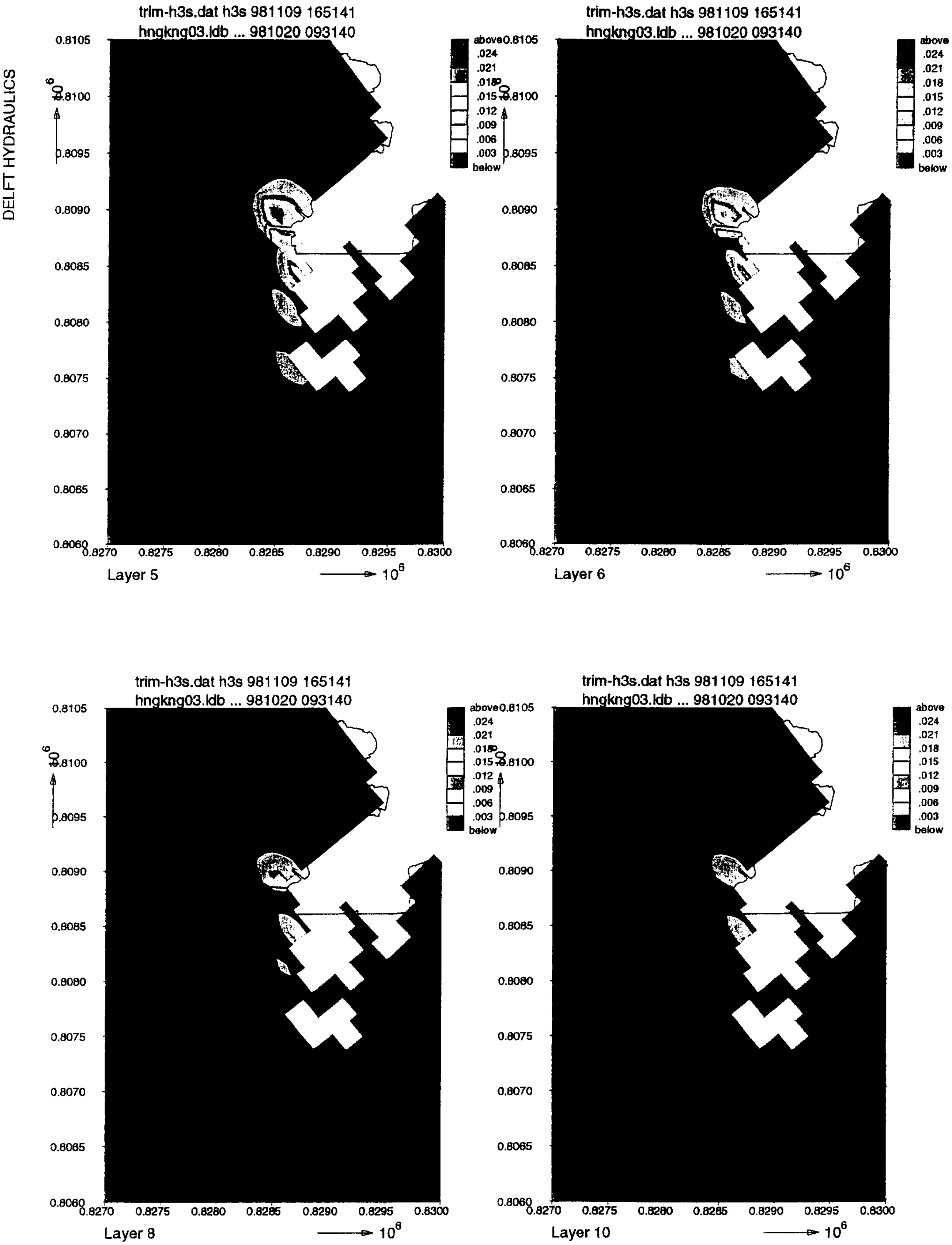


FIGURE 2

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 6-12 JANUARY 1993 (SPRING TIDE)
DRY SEASON; LAYERS 5,6,8,10; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

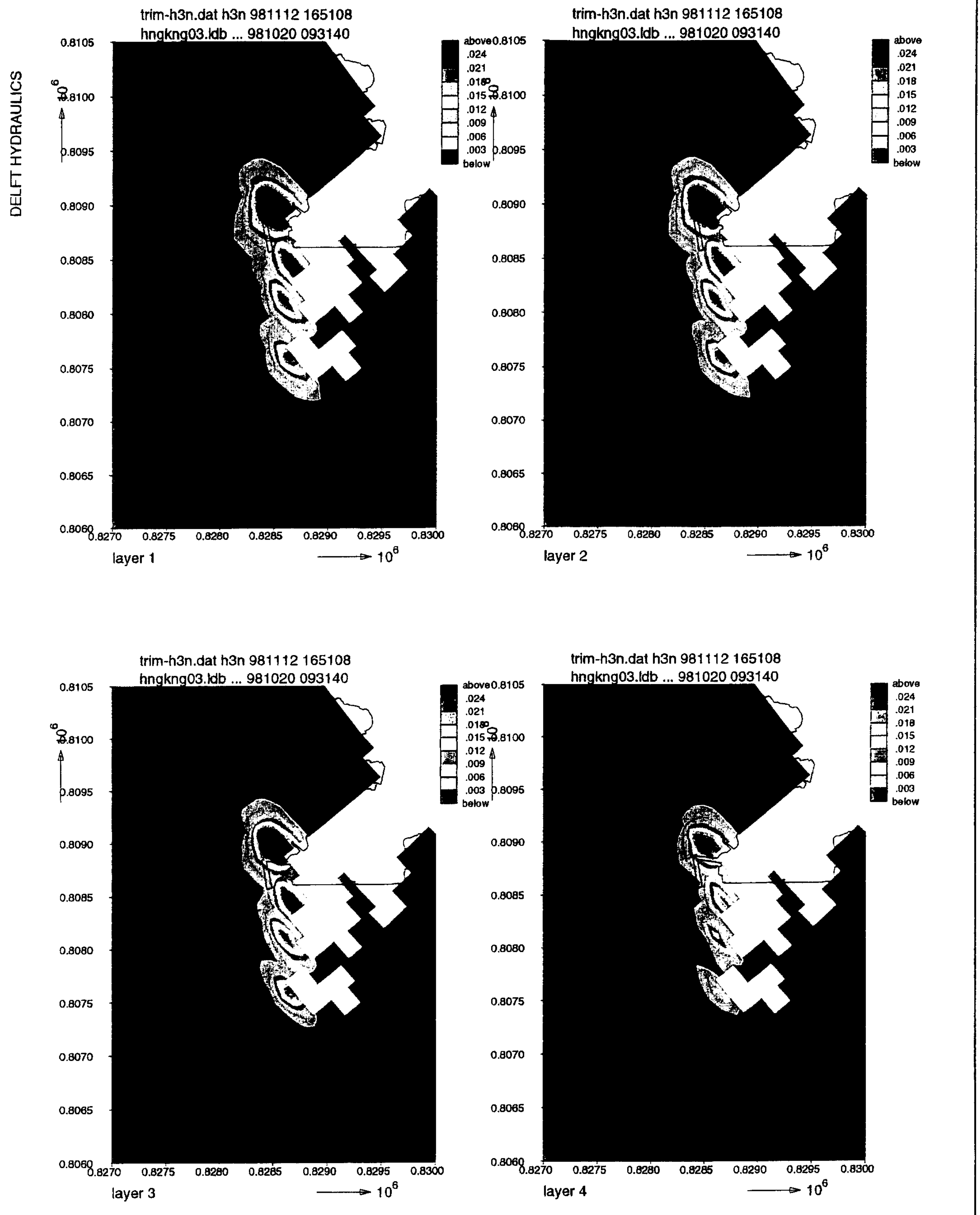


FIGURE 3

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 13-19 JANUARY 1993 (NEAP TIDE)
DRY SEASON; LAYERS 1 TO 4; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

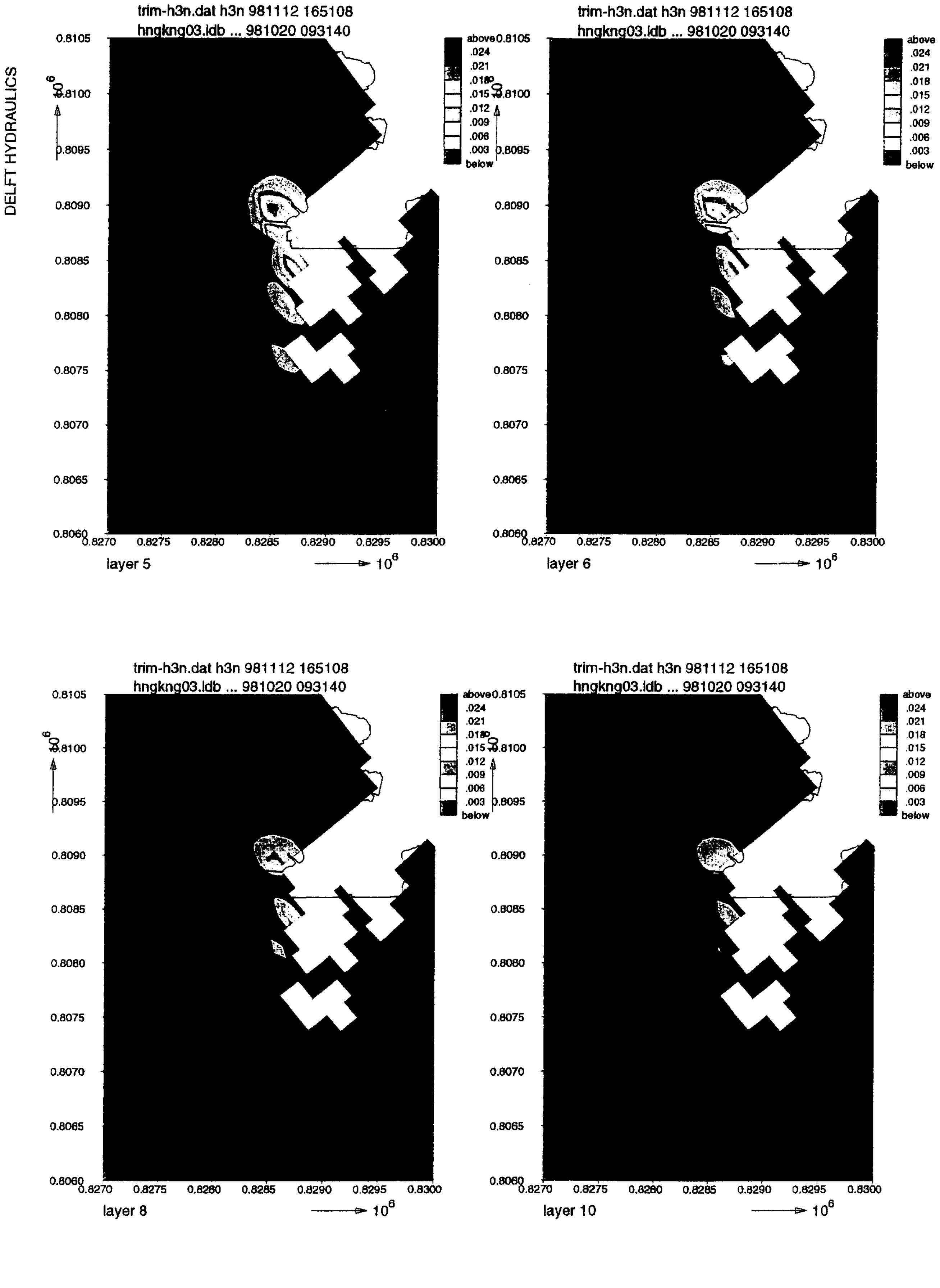


FIGURE 4

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 13 - 19 JANUARY 1993 (NEAP TIDE)
DRY SEASON; LAYERS 5,6,8,10; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

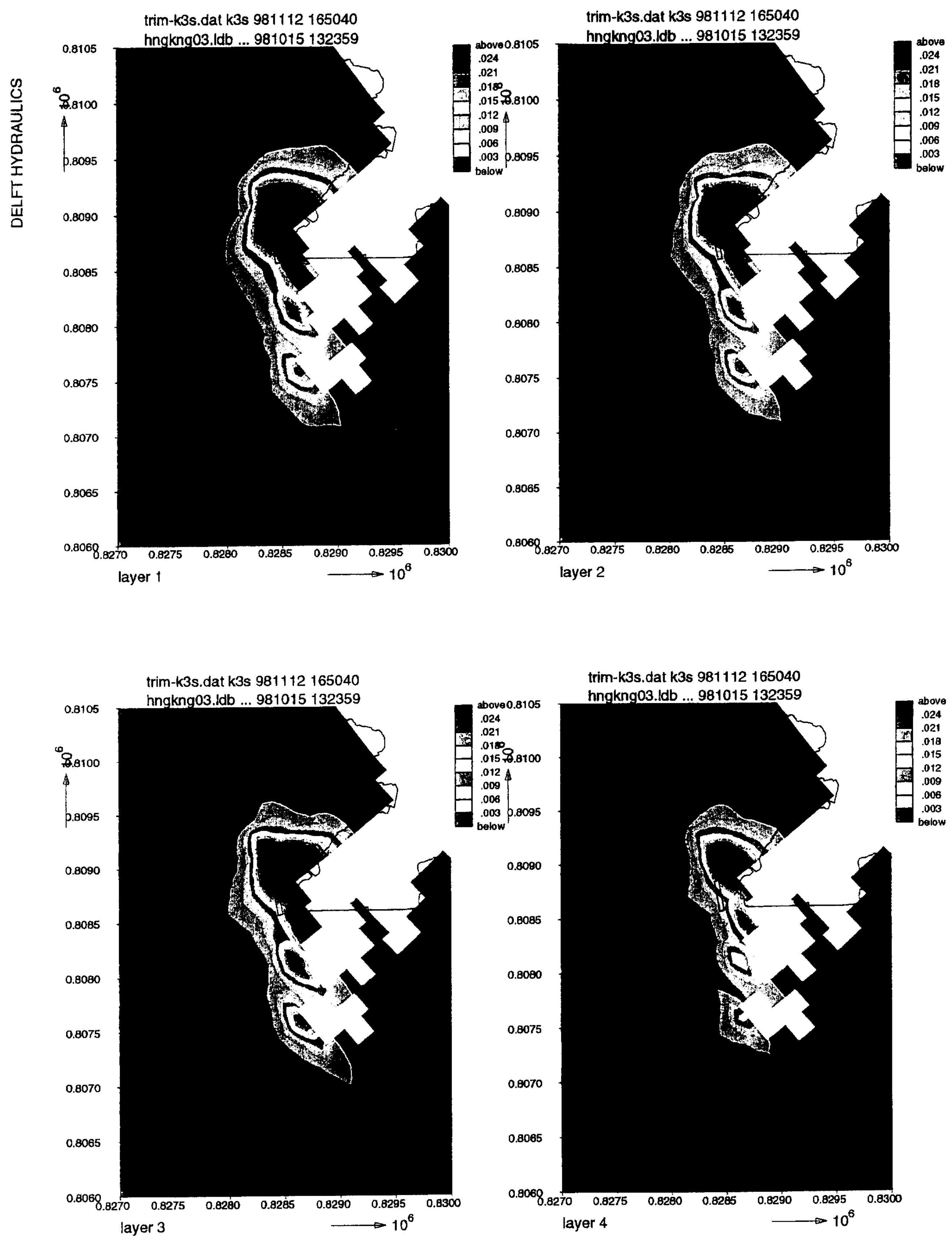


FIGURE 5

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 8 - 14 AUGUST 1992 (SPRING TIDE)
WET SEASON; LAYERS 1 TO 4; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

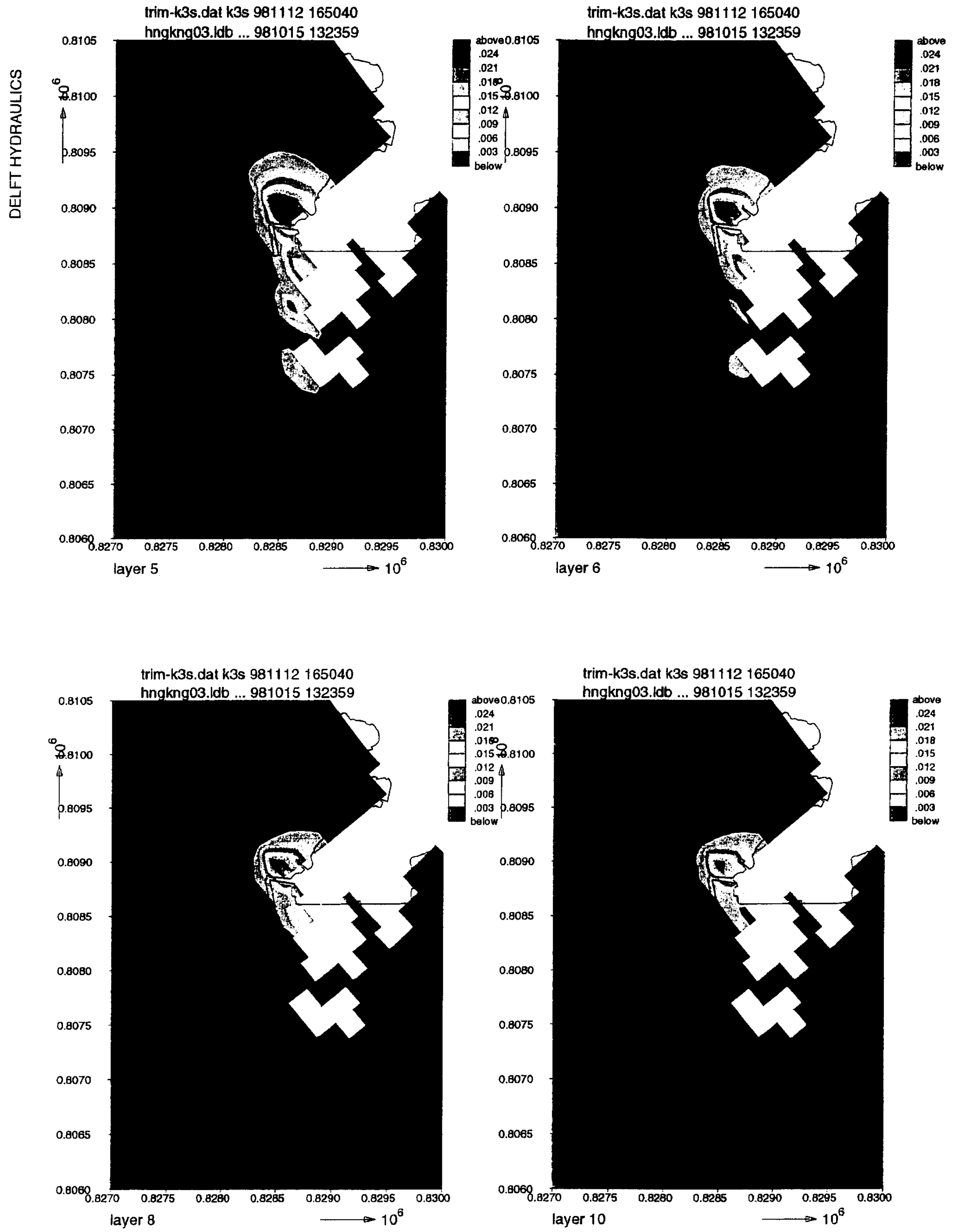


FIGURE 6

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 8 - 14 AUGUST 1992 (SPRING TIDE)
WET SEASON; LAYERS 5,6,8,10; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

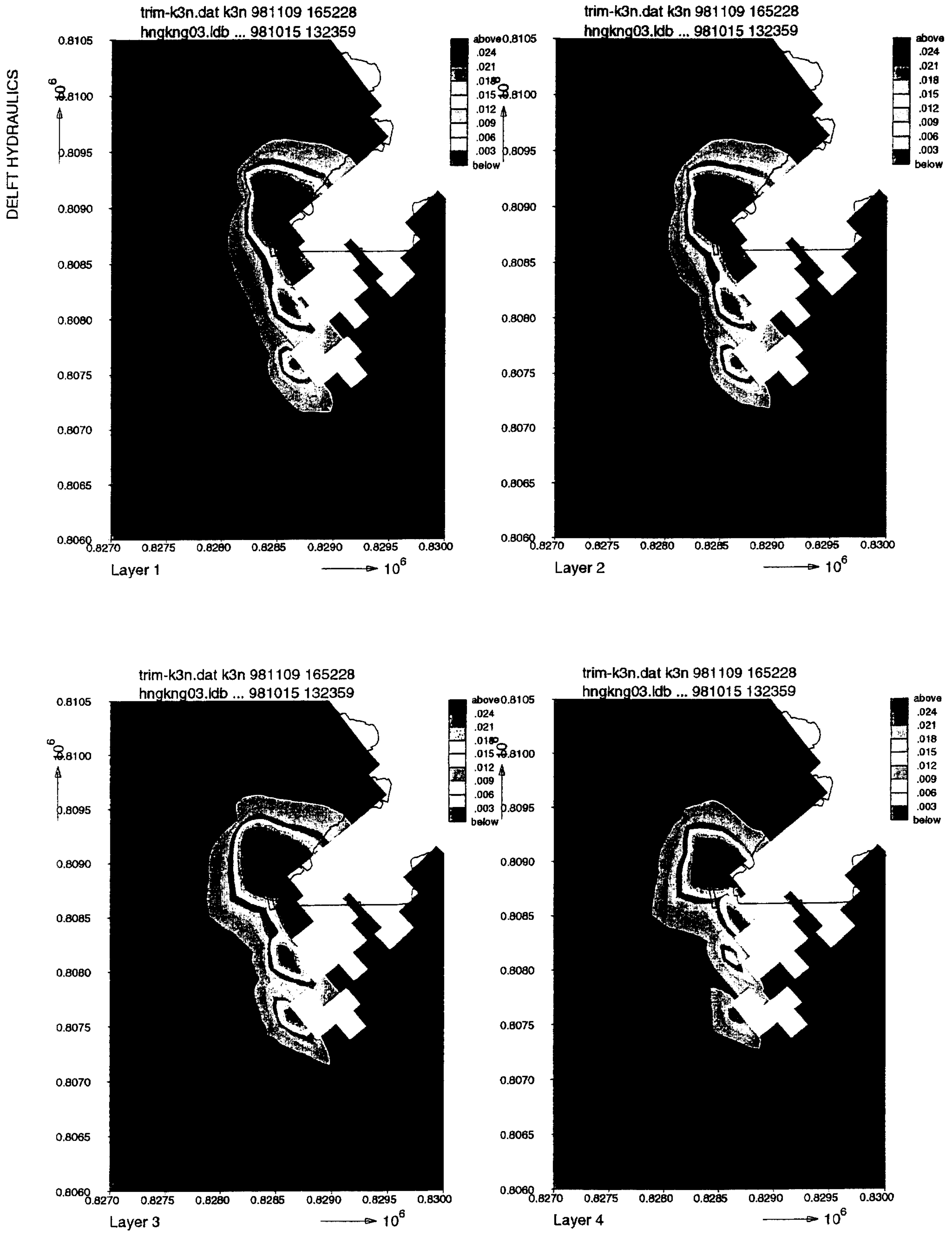


FIGURE 7

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 1 - 7 AUGUST 1992 (NEAP TIDE)
WET SEASON; LAYERS 1 TO 4; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

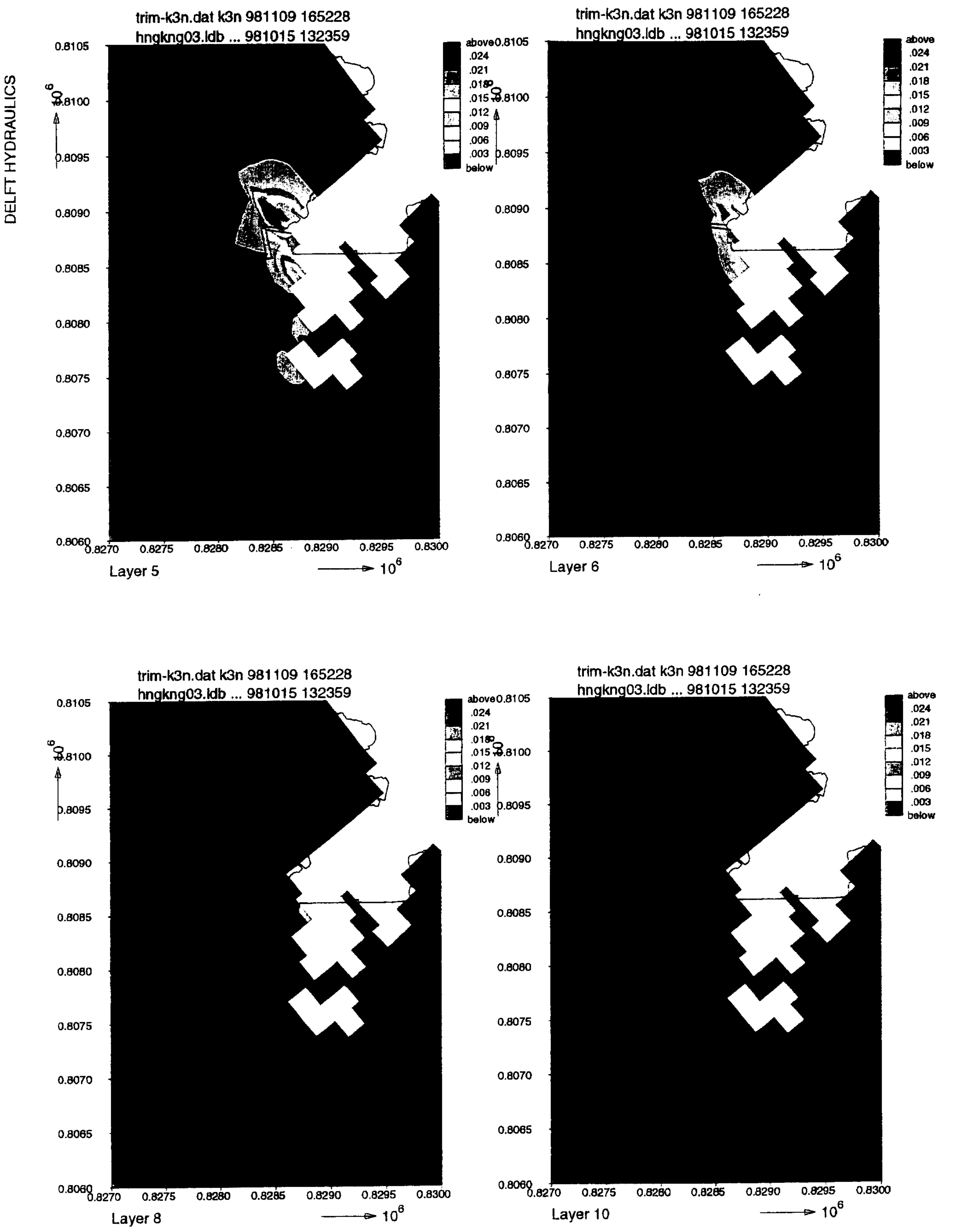


FIGURE 8

POWER STATION + WEIF EXTENSION; SCENARIO 4
MAXIMUM CHLORIDE (mg/l) FOR 1 - 7 AUGUST 1992 (NEAP TIDE)
WET SEASON; LAYERS 5,6,8,10; WITH DECAY (T90 = 1800 SEC)

Environmental Resources Management

ERM

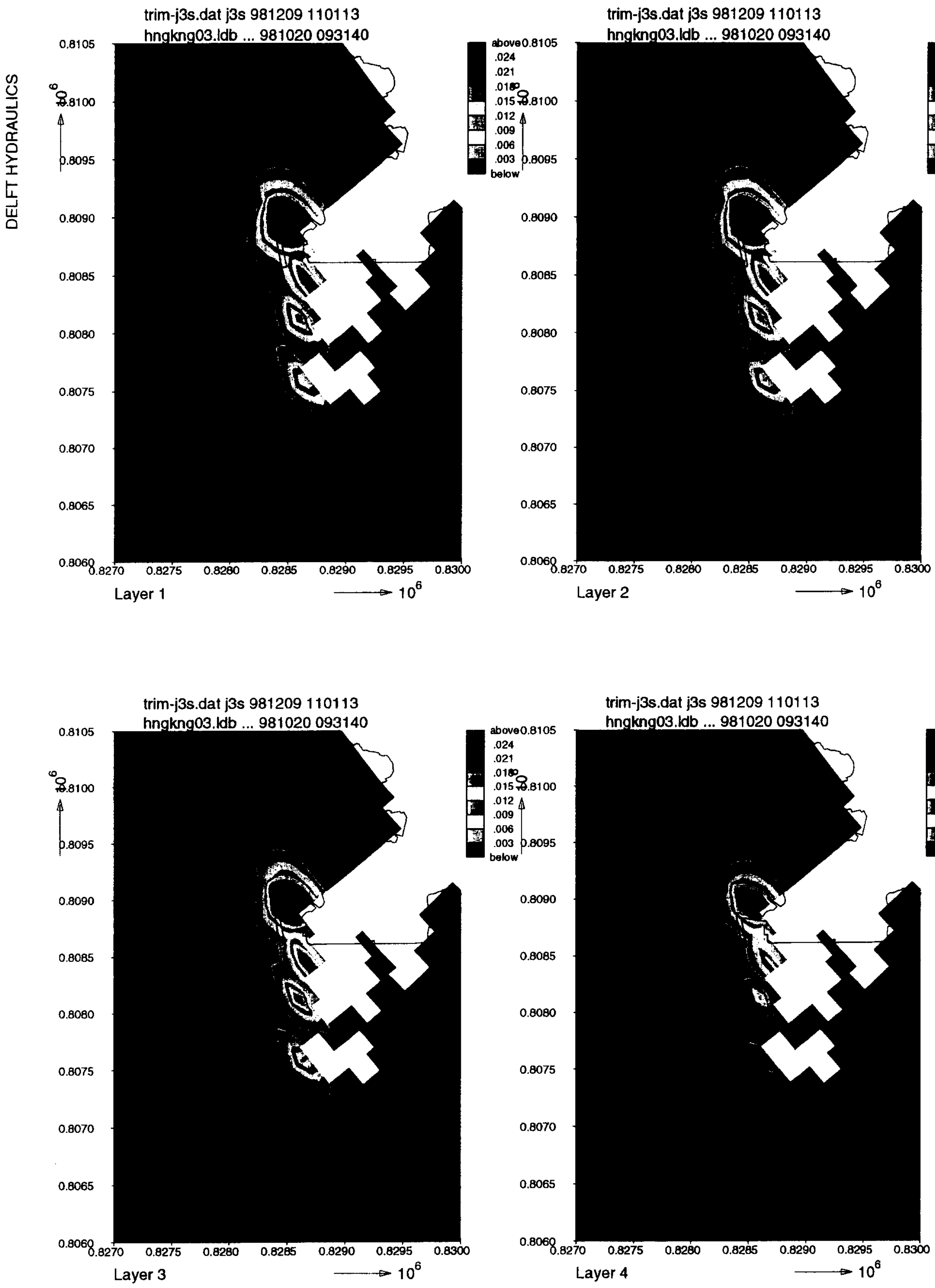


FIGURE 9

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 6-12 JANUARY 1993 (SPRING TIDE)
DRY SEASON; LAYERS 1 TO 4; WITH DECAY (T90=1800 SEC)

FILE: C1830/text2
DATE: 17/12/98

Environmental Resources Management

ERM

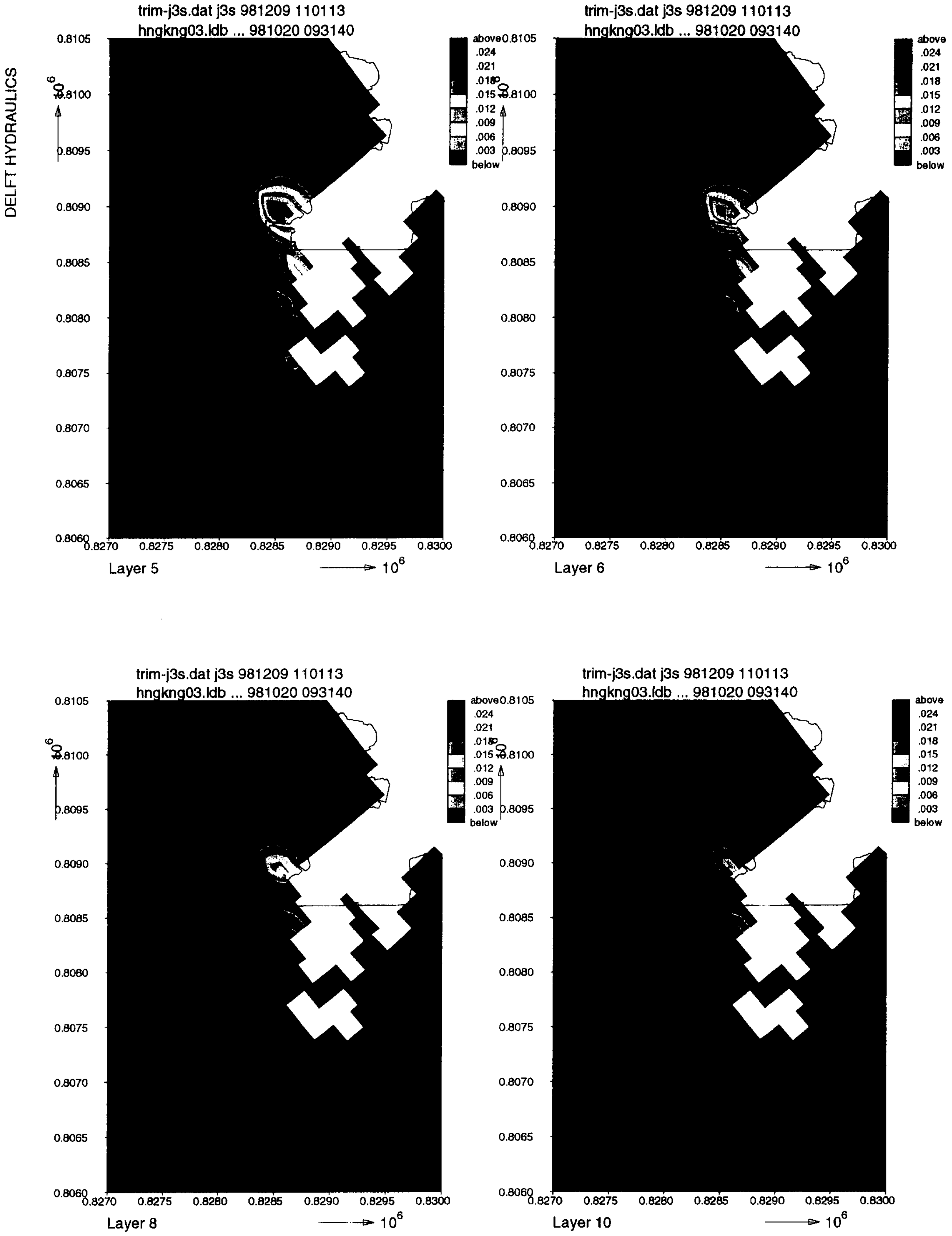


FIGURE 10

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 6-12 JANUARY 1993 (SPRING TIDE)
DRY SEASON; LAYERS 5,6,8,10; WITH DECAY (T90=1800SEC)

FILE: C1830/text2
DATE: 17/12/98

Environmental Resources Management

ERM

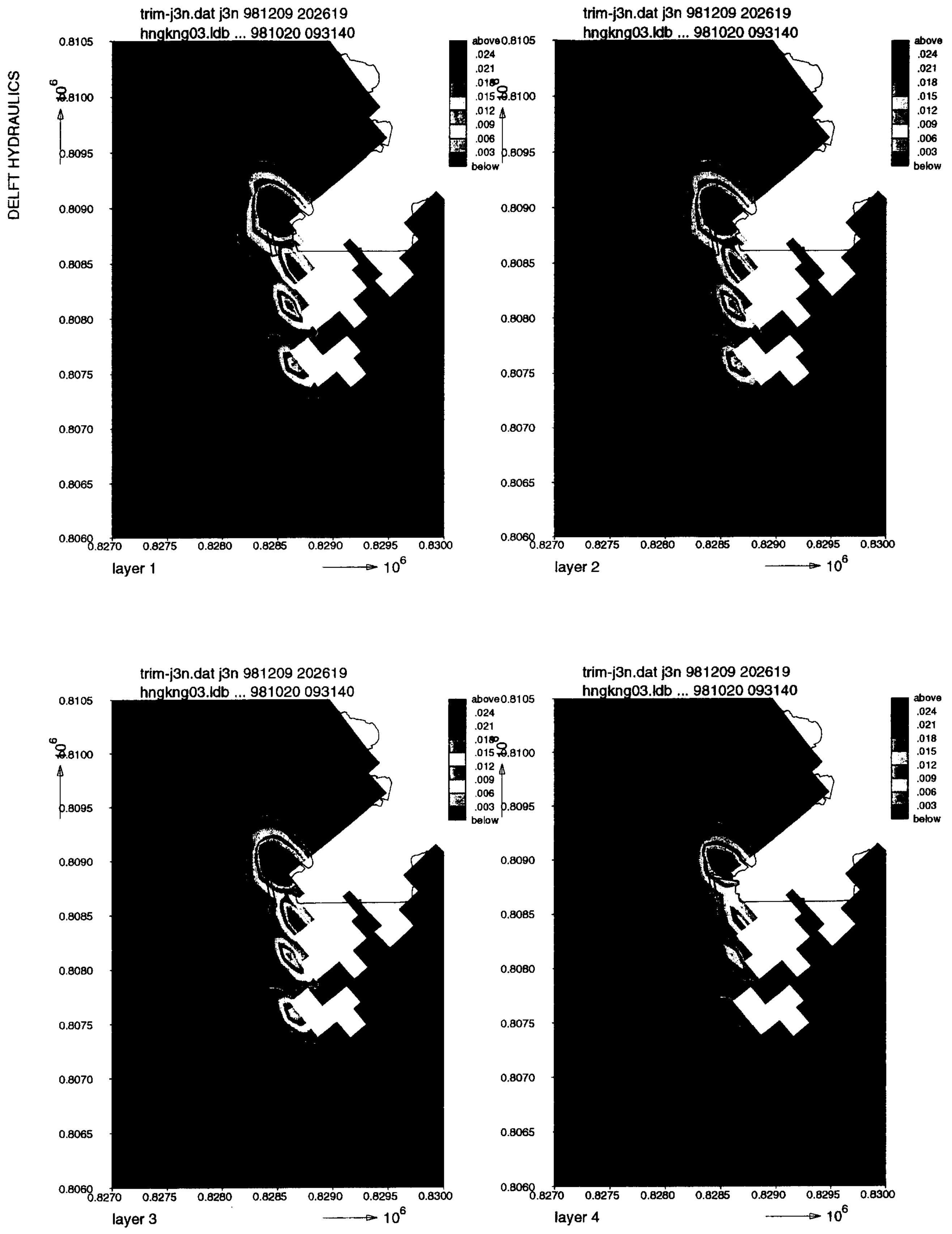


FIGURE 11

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 13-19 JANUARY 1993 (NEAP TIDE)
WET SEASON; LAYERS 1 TO 4; WITH DECAY (T90=1800SEC)

FILE: C1830/text2
DATE: 17/12/98

Environmental Resources Management

ERM

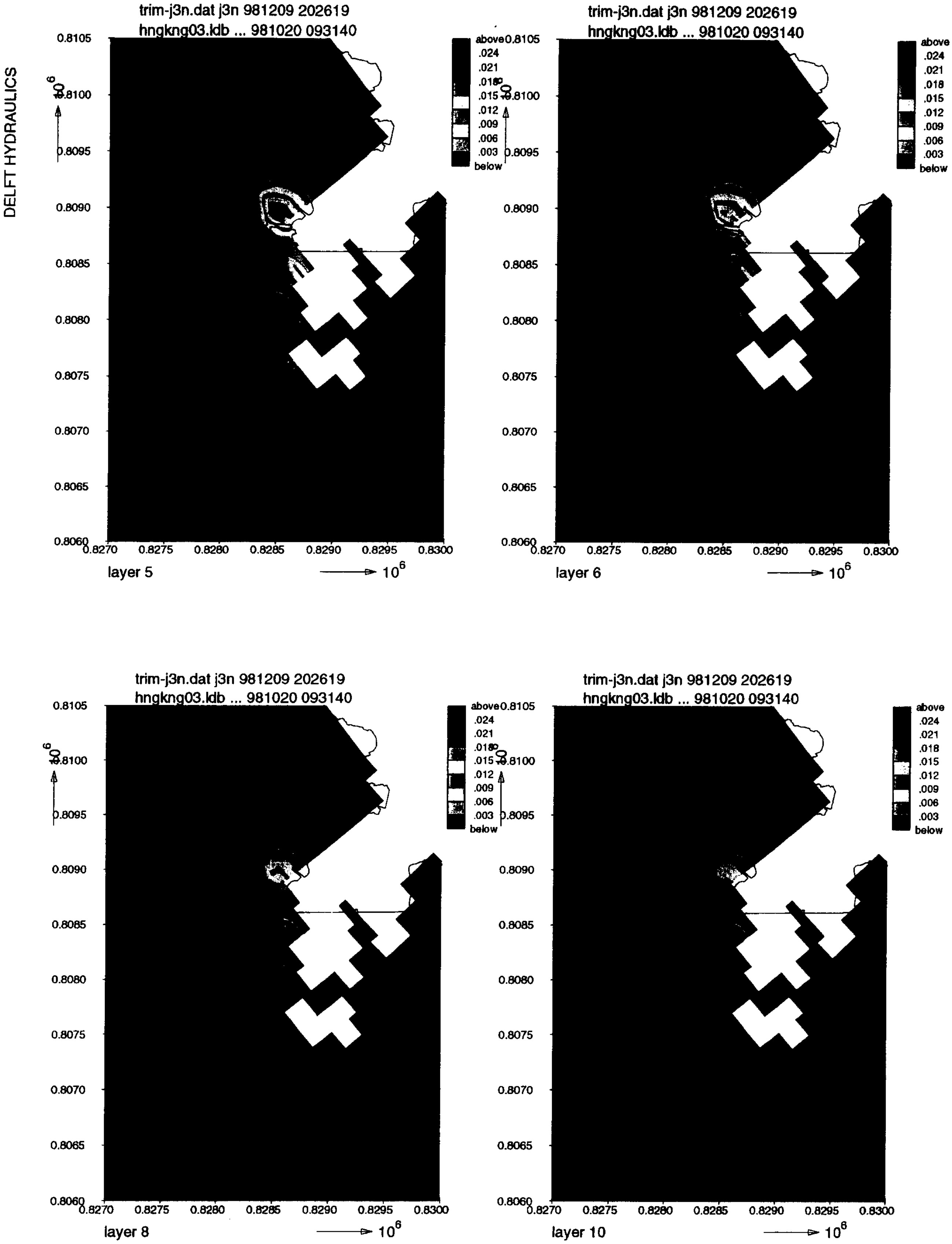


FIGURE 12

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 13-19 JANUARY 1993 (NEAP TIDE)
WET SEASON; LAYERS 5,6,8,10; WITH DECAY (T90=1800SEC)

FILE: C1830/text2
DATE: 17/12/98

Environmental Resources Management

ERM

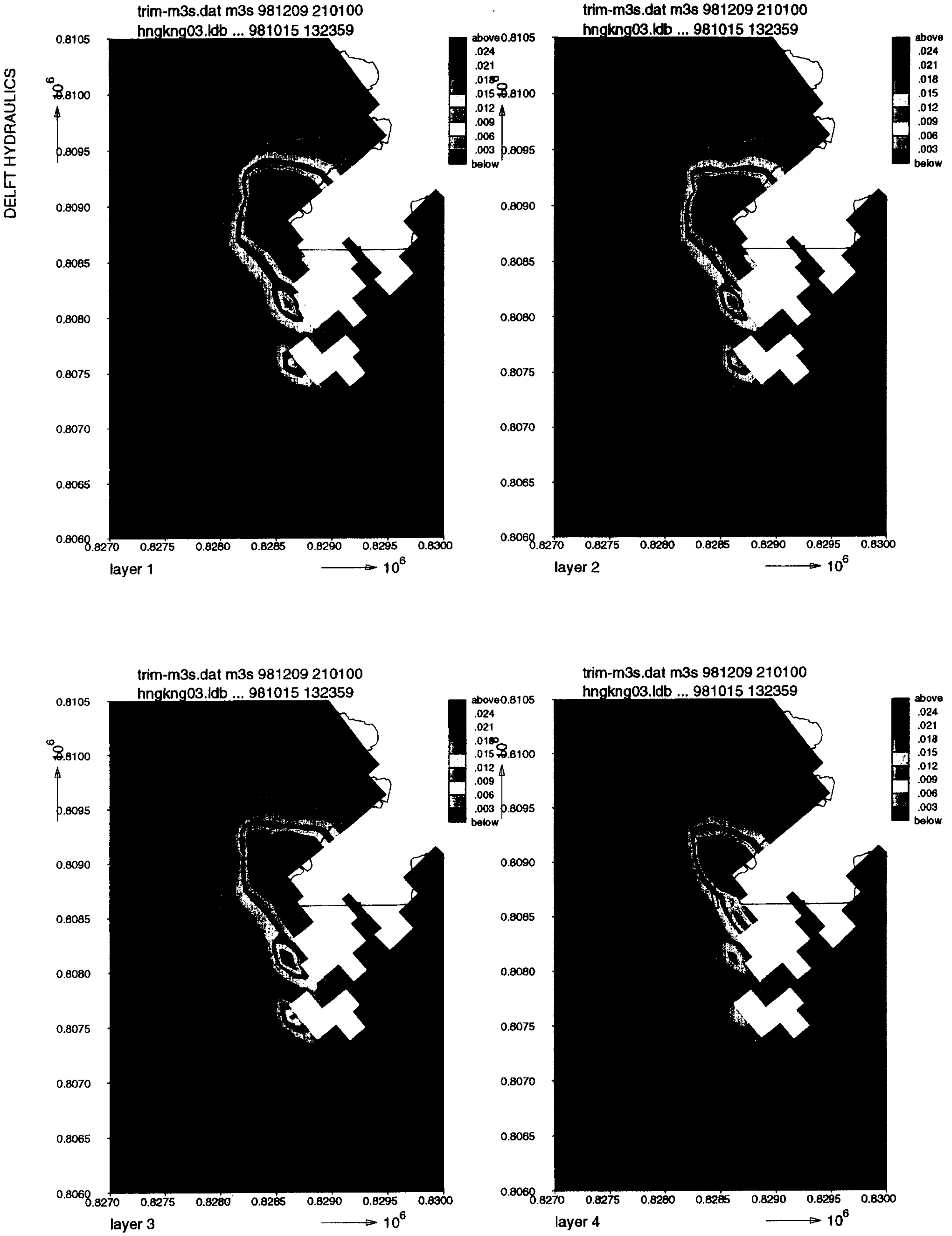


FIGURE 13

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 8-14 AUGUST 1992 (SPRING TIDE)
WET SEASON; LAYERS 1 TO 4; WITH DECAY (T90=1800SEC)

FILE: C1830/text2
DATE: 17/12/98

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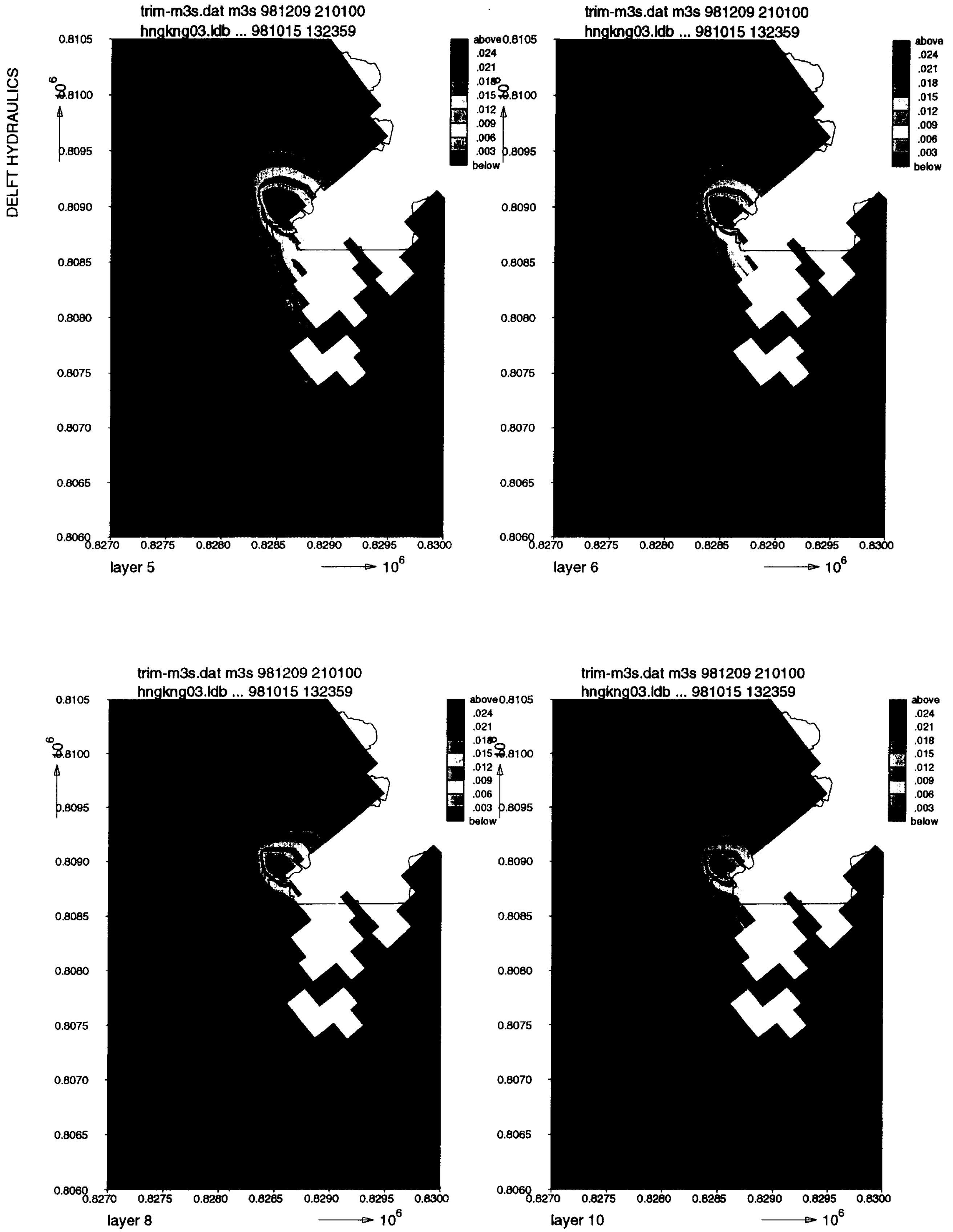

FIGURE 14

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 8-14 AUGUST 1992 (SPRING TIDE)
WET SEASON; LAYERS 5,6,8,10; WITH DECAY (T90=1800SEC)

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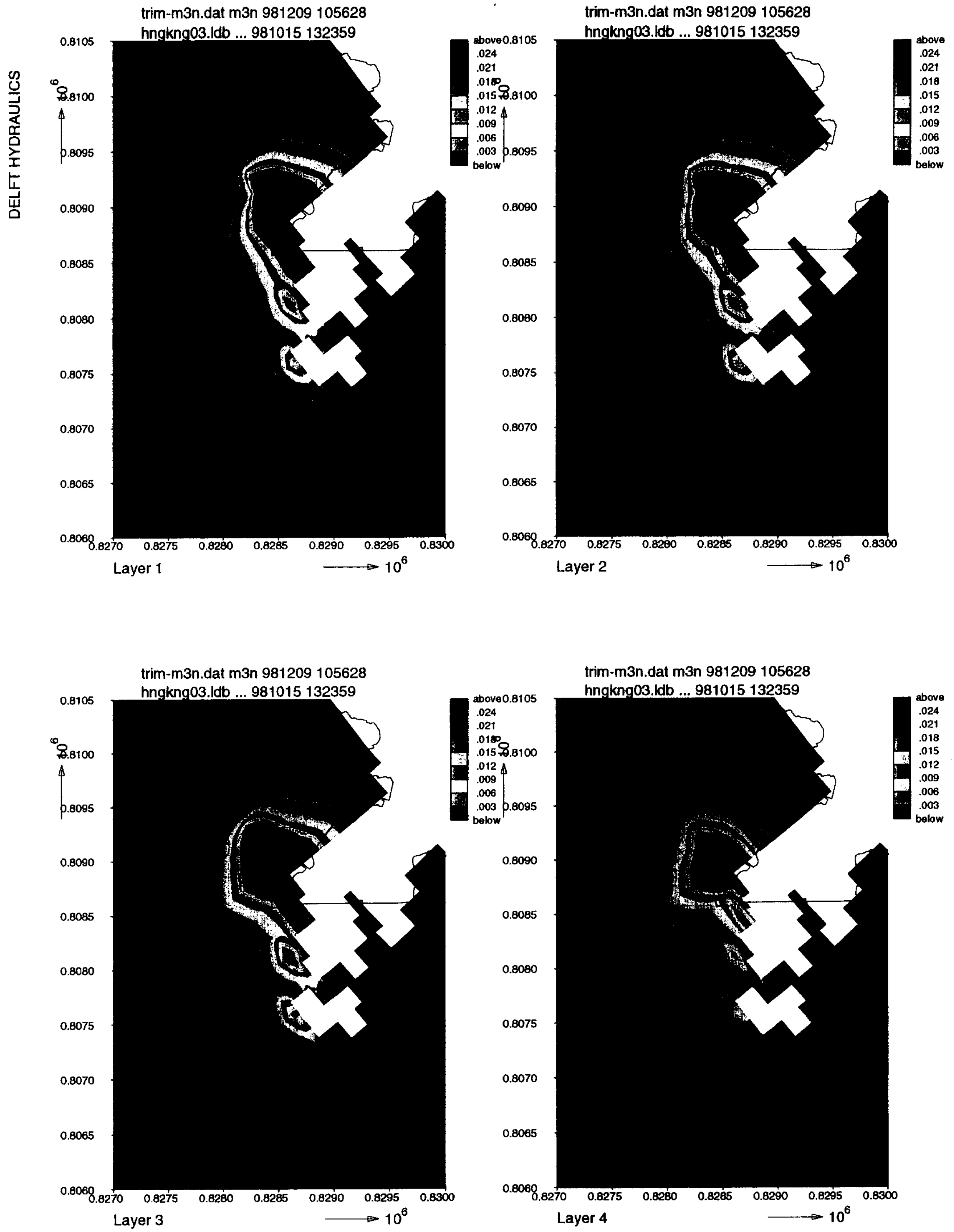

FIGURE 15

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 1-7 AUGUST 1992 (NEAP TIDE)
WET SEASON; LAYERS 1 TO 4; WITH DECAY (T90=1800SEC)

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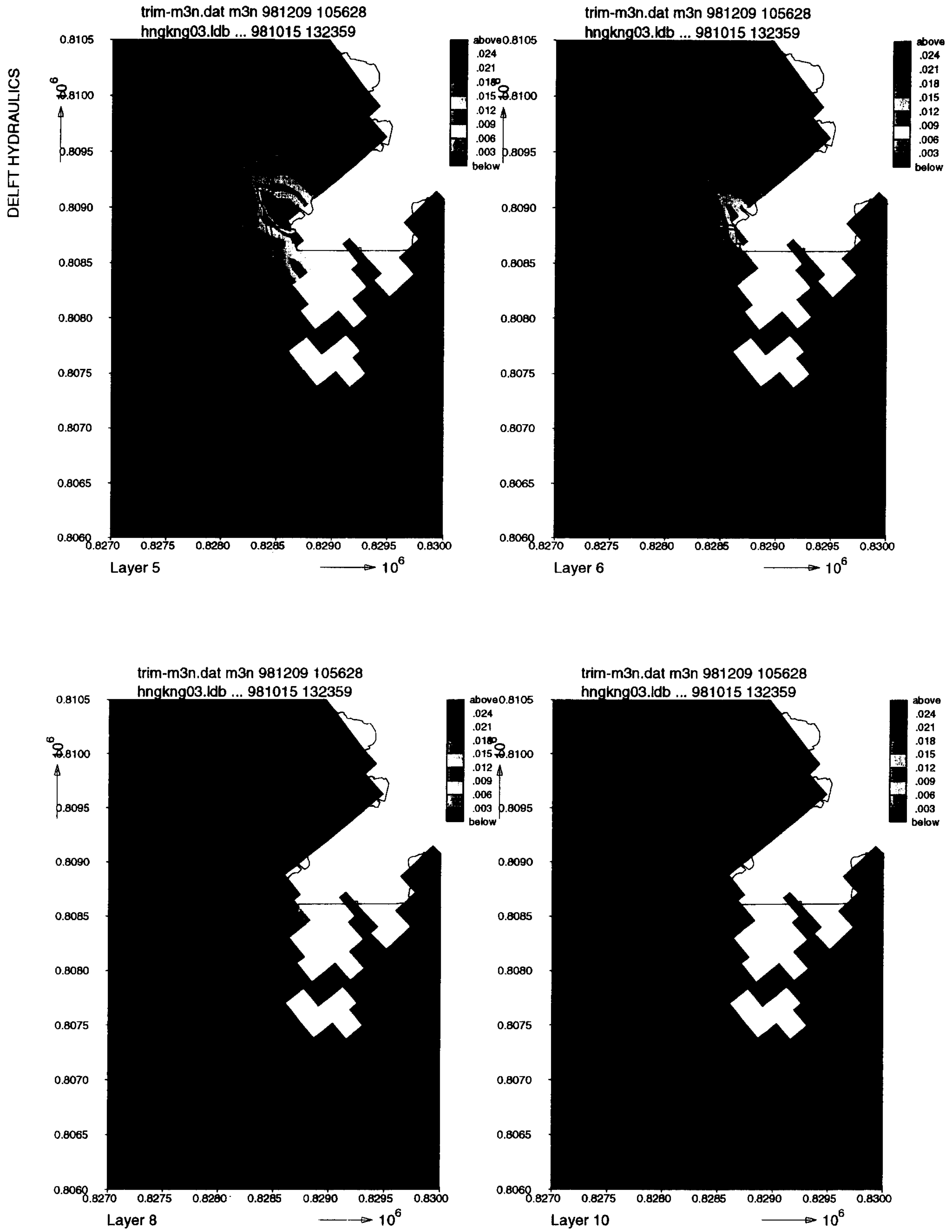

FIGURE 16

POWER STATION + WEIF EXTENSION; SCENARIO 5
MAXIMUM CHLORIDE (mg/l) FOR 1-7 AUGUST 1992 (NEAP TIDE)
WET SEASON; LAYERS 5,6,8,10; WITH DECAY (T90=1800SEC)

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Annex B6-1

Construction Noise Sample Calculations

Table B6-1a Calculation of Total Sound Power Level (SWL) Emissions from Construction Activities During 7/ 2000; Dredging, Filing for Foundation and Seawall and Placing Vertical Seawall Block.

Active Equipment (PMEs)	Hours/ Day	Ref.SWL	PMEs Active		Corrected SWLs		
			No.	dB	0700 - 1900	1900 - 2300	2300 - 0700
Dredging							
Grab Dredger	24	112	2	+3	115	115	115
Tug Boat	24	110	2	+3	113	113	113
Trailer Suction Hopper Dredge	24	111	1	0	111	111	111
Filling for Foundation And Seawall							
Tug Boat	16	110	2	+3	113	113	-
Grab Dredger	16	112	2	+3	115	115	-
Derrick Barge	16	104	2	+3	107	107	-
Placing Vertical Seawall Block							
Derrick Barge	16	104	3	+5	109	109	-
Total					**121**	**121**	**117**

Table B6-1b Calculation of Effects of Distance, Atmospheric Absorption, Shielding and Reflections on Construction Noise Levels to be Experienced at the Four Noise Sensitive Receivers (NSRs).

NSR	Distance (m)	Distance Effect (GM-TM, Table 5) (dB)	Atmospheric Absorption (2.7 dB/km)	Barrier Shielding (dB)	Facade Reflection Effect (dB)	Total Attenuation (dB)
1	1250 to 1450	-70.5	-3.5	0	+3	-71.0
2	950 to 1000	-68.0	-2.5	-10	+3	-77.5
3	1500	-71.5	-4.0	-10	+3	-82.5
4	1300	-70.5	-3.5	-10	+3	-81.0

Table B6-1c Calculation of Corrected Noise Levels (CNLs) from Construction Activities During 7/ 2000 (Dredging, Filing for Foundation and Seawall and Placing Vertical Seawall Block) at the Four NSRs.

NSR	Daytime (0700 - 1900 Hours)			Evening (1900 - 2300 Hours)			Nighttime (2300 to 0700 Hours)		
	SWL (dBA)	Total Attenuation (dBA)	CNL (dBA)	SWL (dBA)	Total Attenuation (dBA)	CNL (dBA)	SWL (dBA)	Total Attenuation (dBA)	CNL (dBA)
1	121	-71.0	50.0	121	-71.0	50.0	117	-71.0	46.0
2	121	-77.5	43.5	121	-77.5	43.5	117	-77.5	39.5
3	121	-82.5	38.5	121	-82.5	38.5	117	-82.5	34.5
4	121	-81.0	40.0	121	-81.0	40.0	117	-81.0	36.0

Annex B6-2

Operational Noise Sample Calculations

Table B6-2a

NSR : Wang Long, Ko Long

Source	Distance to NSR (m)	31.5	63	125	250	500	1K	2K	4K	8K	SPL dB(A)
ENCLOSURE 1A	1626	19	16	1	0	0	0	0	0	0	0
ENCLOSURE 1B	1538	22	20	5	0	0	0	0	0	0	0
ENCLOSURE 1C	1609	23	21	6	0	0	0	0	0	0	0
ENCLOSURE 1D	1555	24	22	6	0	0	0	0	0	0	0
ENCLOSURE 1E	1581	29	27	11	5	1	0	0	0	0	4.2
ENCLOSURE 2A	1511	20	17	2	0	0	0	0	0	0	0
ENCLOSURE 2B	1428	23	21	6	0	0	0	0	0	0	0
ENCLOSURE 2C	1497	24	22	7	0	0	0	0	0	0	0
ENCLOSURE 2D	1439	24	22	7	1	0	0	0	0	0	0
ENCLOSURE 2E	1468	29	27	12	6	2	0	0	0	0	4.9
INTAKE 1	1595	12	10	6	5	3	1	0	0	0	4.9
HRSG 1A	1569	28	29	27	18	10	1	0	0	0	14.7
HRSG 1B	1569	29	31	29	19	12	1	0	0	0	16
INTAKE 2	1569	12	10	7	5	3	1	0	0	0	5.1
HRSG 2A	1543	29	30	28	19	11	2	0	0	0	15.7
HRSG 2B	1543	29	31	29	19	12	2	0	0	0	16.2
INTAKE 3	1535	12	10	7	5	4	2	0	0	0	5.4
HRSG 3A	1508	29	30	28	18	11	2	0	0	0	15.3
HRSG 3B	1508	29	31	29	20	12	2	0	0	0	16.4
INTAKE 4	1479	12	10	7	6	4	2	0	0	0	6
HRSG 4A	1451	29	30	28	19	12	3	0	0	0	15.8
HRSG 4B	1451	29	31	29	20	13	3	0	0	0	16.8
INTAKE 5	1454	12	10	7	6	4	2	0	0	0	6.3
HRSG 5A	1426	29	31	29	20	12	3	0	0	0	16.4
HRSG 5B	1426	29	31	29	20	13	3	0	0	0	17
INTAKE 6	1422	12	10	8	6	5	3	0	0	0	6.6
HRSG 6A	1392	29	31	29	19	12	3	0	0	0	16.4
HRSG 6B	1392	30	32	30	20	13	3	0	0	0	17.2
EXHAUST 1	1518	37	27	22	16	10	0	0	0	0	12.2
EXHAUST 2	1399	38	28	24	17	12	0	0	0	0	13.8
TRANSFORMER 1	1650	16	18	21	13	7	0	0	0	0	9.5
TRANSFORMER 2	1625	16	18	22	14	6	0	0	0	0	9.5
TRANSFORMER 3	1592	16	18	22	14	7	0	0	0	0	9.8
TRANSFORMER 4	1538	16	18	22	14	8	0	0	0	0	10.3
TRANSFORMER 5	1514	16	18	22	14	8	0	0	0	0	10.4
TRANSFORMER 6	1483	17	18	22	14	8	0	0	0	0	10.6
COOLING WATER PUMP	1298	24	19	24	20	13	11	0	0	0	16.1
SPL Total (dBA)		44	43	40	31	25	16	5	0	0	28.3

Table B6-2a (Cont'd)

NSR : Hung Shing Ye

Source	Distance to NSR (m)	31.5	65	125	250	500	1K	2K	4K	8K	SPL dB(A)
		Octave Band Centre Frequency (Hz)									
ENCLOSURE 1A	1717	23	20	5	0	0	0	0	0	0	0
ENCLOSURE 1B	1681	33	32	20	15	13	0	0	0	0	13.3
ENCLOSURE 1C	1738	26	24	9	2	0	0	0	0	0	1.2
ENCLOSURE 1D	1659	34	34	21	17	14	1	0	0	0	14.9
ENCLOSURE 1E	1698	34	33	20	16	13	0	0	0	0	13.7
ENCLOSURE 2A	1671	24	22	8	1	0	0	0	0	0	0
ENCLOSURE 2B	1646	33	32	20	16	13	0	0	0	0	13.6
ENCLOSURE 2C	1698	26	23	9	2	0	0	0	0	0	1
ENCLOSURE 2D	1617	34	34	22	17	15	1	0	0	0	15.2
ENCLOSURE 2E	1657	34	33	21	16	13	0	0	0	0	13.9
INTAKE 1	1687	19	18	17	17	15	12	2	0	0	16.4
HRSG 1A	1648	32	34	32	23	14	3	0	0	0	19.3
HRSG 1B	1648	39	43	43	36	30	21	9	0	0	32.3
INTAKE 2	1677	21	21	20	21	21	20	12	0	0	23.3
HRSG 2A	1637	39	43	43	36	30	21	9	0	0	32.3
HRSG 2B	1637	39	43	43	36	30	21	9	0	0	32.3
INTAKE 3	1663	21	21	21	22	21	20	12	0	0	23.4
HRSG 3A	1623	33	34	33	24	16	4	0	0	0	20.3
HRSG 3B	1623	39	43	43	36	30	21	9	0	0	32.4
INTAKE 4	1643	21	21	21	22	22	20	12	0	0	23.6
HRSG 4A	1602	33	35	34	25	17	6	0	0	0	21.3
HRSG 4B	1602	39	43	43	36	30	21	9	0	0	32.6
INTAKE 5	1635	22	21	21	22	22	21	12	0	0	23.7
HRSG 5A	1594	36	39	39	32	26	16	4	0	0	28
HRSG 5B	1594	39	43	43	36	30	21	9	0	0	32.6
INTAKE 6	1625	22	21	21	22	22	21	13	0	0	23.7
HRSG 6A	1584	34	36	35	26	18	7	0	0	0	22.6
HRSG 6B	1584	39	43	43	36	30	21	10	0	0	32.7
EXHAUST 1	1597	44	36	33	28	25	6	3	0	0	25
EXHAUST 2	1553	44	36	33	28	26	7	4	0	0	25.3
TRANSFORMER 1	1769	17	18	21	13	6	0	0	0	0	9
TRANSFORMER 2	1758	18	19	23	14	7	0	0	0	0	10.4
TRANSFORMER 3	1746	21	23	27	19	11	0	0	0	0	14.7
TRANSFORMER 4	1726	17	18	22	13	6	0	0	0	0	9.2
TRANSFORMER 5	1719	17	19	22	13	6	0	0	0	0	9.7
TRANSFORMER 6	1710	23	26	31	23	15	0	0	0	0	18.6
COOLING WATER PUMP	1463	34	32	40	37	32	29	7	0	0	33.7
SPL Total (dBA)	TOTAL	51	52	53	46	40	34	22	5	0	42.6

Note:

Each Enclosure is divided into 5 sources (A to E)
Each HRSG unit is divided into 2 sources (A & B)

SPL @ NSRs does not include facade correction (2.5 dBA)

Table B6-2b Derived Noise Level at NSR due to an Individual Source

Description	Octave Band Centre Frequency (Hz)								SWL
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**dB(A)**
GT Intake	94.0	94.0	96.0	98.0	101.0	101.0	102.0	101.0	107.9
Distance Att'n (1688m)	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
Air Att'n	0.5	1.0	2.1	4.2	8.4	16.8	33.5	67.1	
Facade Correction	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SPL @NSR	24	23	23.9	23.8	22.6	14.3	-	-	25.8

Annex B8-1

Sediment Quality Report

1 *INTRODUCTION*

1.1 BACKGROUND

The Hongkong Electric Company, Limited (HEC) have commissioned ERM Hong Kong Ltd (ERM) to undertake an Environmental Impact Assessment (EIA) study for the development of a 1,800 MW gas-fired power station at Lamma Extension (*EIA Study Brief No ESB-001/1998*). Construction of the power station will require reclamation of approximately 22 ha of seabed immediately to the south of the existing Lamma Power Station as shown in *Figure 1.1a*. During the site formation, dredging of marine sediments will be required in the reclamation area. The proposed extent of dredging, based on the assumption that all marine mud will be removed is shown in *Figure 1.1b*. The dredging will take place between December 1999 to July 2000. A sediment sampling and testing programme was submitted on 15 July 1998 and endorsed by the Environmental Protection Department (EPD) on 21 August 1998.

1.2 PURPOSE OF THE REPORT

It is the requirement of the *Work Branch Technical Circular (WBTC) No 22/92* that a Sediment Sampling Report be submitted to the Principal Environmental Protection Department Officer of the Solid Waste Control Group of the EPD before any tendering of dredging is carried out. The purpose of this Sediment Quality Report is therefore to provide details of the sediment sampling and testing programme and present the factual information obtained from the sediment chemistry analysis in terms of the sediment quality of the area to be dredged. The report describes:

- information on the site and sampling location;
- methods of sampling and laboratory analysis performed;
- results of the laboratory analysis;
- interpretation of the laboratory analysis results with respect to their implication on sediment quality; and
- an overall conclusion on the sediment quality in the area to be dredged.

1.3 STRUCTURE OF THIS REPORT

Following this introductory section, this report is organised as follows:

- *Section* 2 presents the methodology for the sediment sampling and testing;

- *Section 3* presents the results of laboratory analysis and assessment of sediment quality; and

- *Section 4* presents the conclusion on the sediment quality of the area to be dredged.

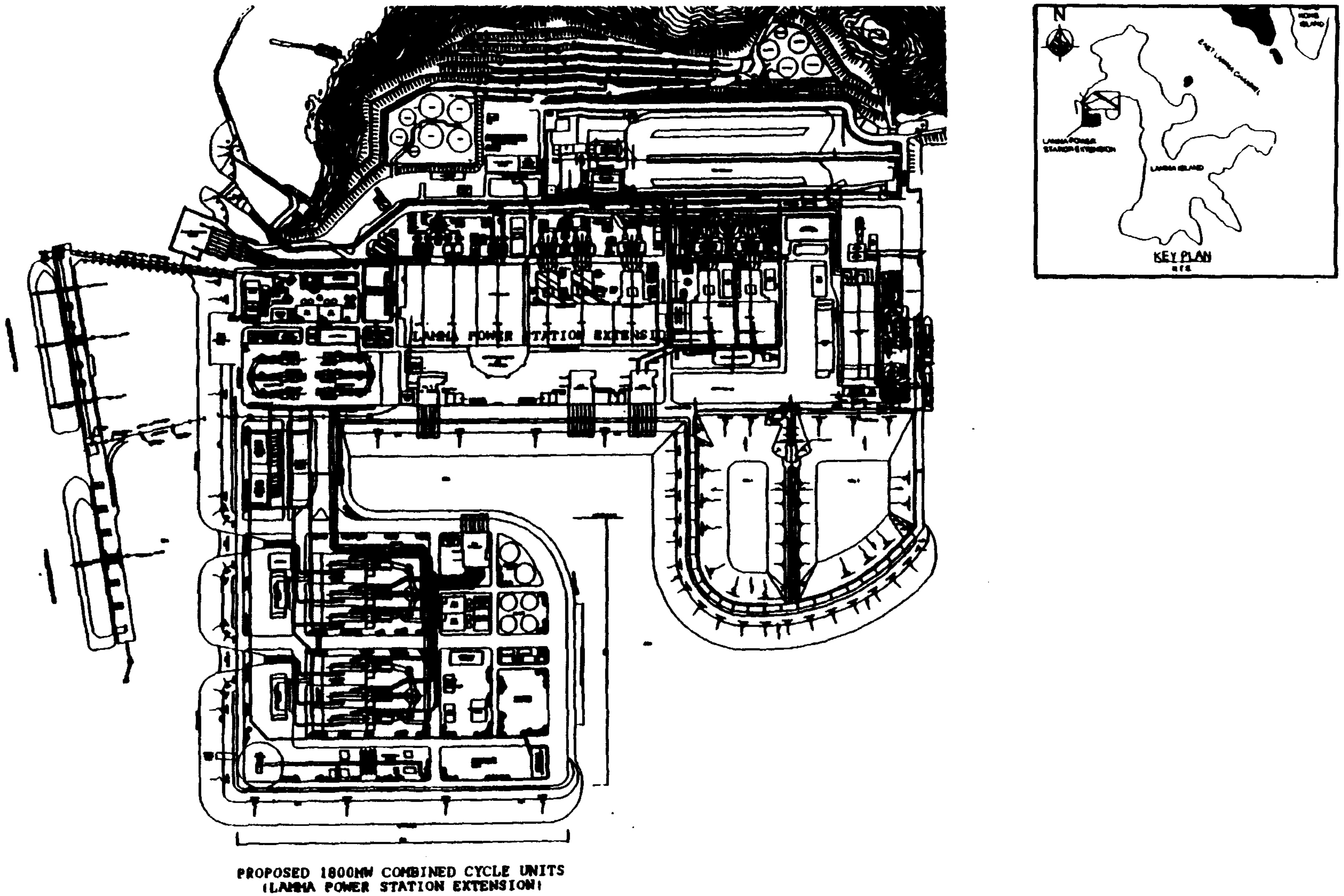

FIGURE 1.1a

LOCATION OF LAMMA POWER STATION EXTENSION

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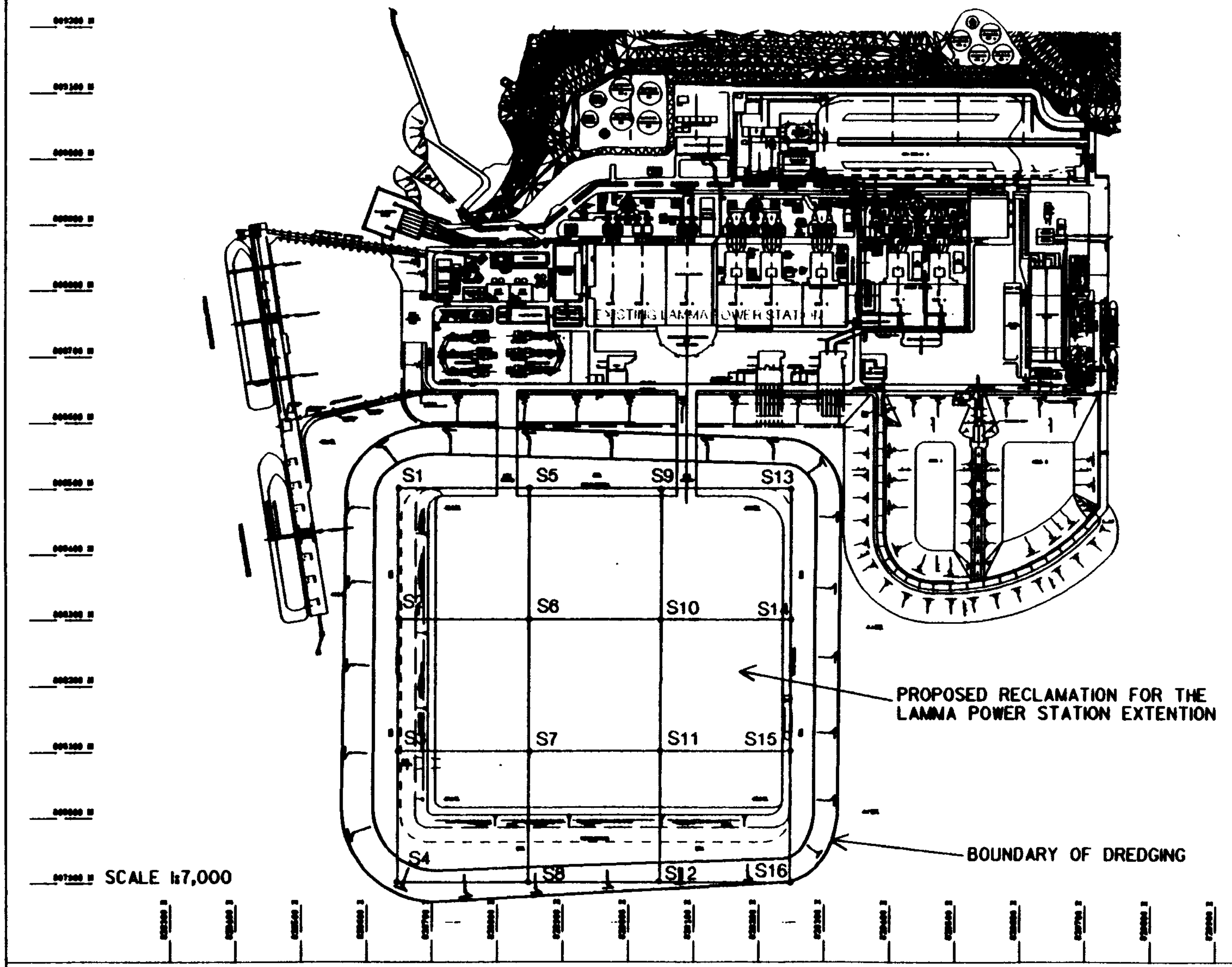

SAMPLING LOCATION	EASTING	NORTHING
S1	828650	808500
S2	828650	808300
S3	828650	808100
S4	828650	807900
S5	828850	808500
S6	828850	808300
S7	828850	808100
S8	828850	807900
S9	829050	808500
S10	829050	808300
S11	829050	808100
S12	829050	807900
S13	829250	808500
S14	829250	808300
S15	829250	808100
S16	829250	807900

FIGURE 1.1b

SEDIMENT SAMPLING LOCATION

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2 SAMPLING & TESTING METHODOLOGY

2.1 SURVEY PLANNING

2.1.1 *Survey Design*

Sediment monitoring data (see *Annex B8-1a*) obtained from the turning basin enlargement works for the existing Lamma Power Station[1] indicate that the sediment in the area is uncontaminated (Class A) in accordance with EPD's *Technical Circular No 1-1-92*. In accordance with the sampling guideline outlined in *Works Branch Technical Circular (WBTC) 22/92*, a total of 16 vibrocore stations were selected based on a grid size of 200m x 200m. The vibrocore stations are shown in *Figure 1.1b*. At each vibrocore station, vibrocores were taken down to marine deposit and alluvium or rock interface in order to determine the vertical profile of the concentration of the seven heavy metals (including cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn)) stated in the *WBTC 22/92* and the depth of marine deposit at each vibrocore station.

2.1.2 *Mobilisation*

The Hong Kong metric grid coordinates of the vibrocore stations are given in *Figure 1.1b*. Equipment was loaded on to vessels and the vessels were towed to site. The field sampling works were undertaken between 23 July 1998 and 29 July 1998. Two to three vibrocores were retrieved within each working day during the sampling period.

2.1.3 *Equipment*

The vessels, vibrocore system and sample storage equipment used to perform the field survey work are listed in *Table 2.1a*.

Table 2.1a ***List of Required Equipment***

Equipment	Function	Provided by
MARINE VESSELS		
Barge/Drilling vessel with drilling tower, mooring winches, hydraulic power pack and generator	To serve as a base for drilling operations	Bachy Soletanche
Tug boat	To position the drilling vessel	Bachy Soletanche
General transport vessel, eg sampan	To provide marine transport for sampling crew, and HEC and ERM staff	Bachy Soletanche
POSITIONING EQUIPMENT		
A DGPS receiver	Setting out of vibrocore locations	Bachy Soletanche

[1] Hongkong Electric Company, Limited (October 1997). Sediment Quality Report for the Turning Basin Enlargement Works at Lamma Power Station.

Equipment	Function	Provided by
Battery pack	To provide power to the receiver	Bachy Soletanche
Antenna	Setting out of vibrocore locations	Bachy Soletanche
VIBROCORE SYSTEM		
3m x 0.1m Vibrocore barrel with rigid PVC liner	Retrieval of vibrocore	Bachy Soletanche
Drill Rods	Retrieval of vibrocore	Bachy Soletanche
Basket core catcher	Retrieval of vibrocore	Bachy Soletanche
Piston	To aid core recovery from vibrocore barrel	Bachy Soletanche
SAMPLE MIXING AND STORAGE		
Stainless steel bowl	To mix sediments within each sample	Bachy Soletanche
Stainless steel spoon	To mix sediments within each sample	Bachy Soletanche
1 litre glass jars with Teflon lined lids	To contain sediment samples for sediment chemistry analyses	Materialab
Polypropylene plastic bag	To contain sediment sampling jar	Bachy Soletanche
Indelible ink pens	To mark on sample bottles	Bachy Soletanche
Chain-of-custody forms	QC procedure	Bachy Soletanche
Cooler boxes at 4°C	To chill collected samples	Bachy Soletanche

2.2 *SAMPLE COLLECTION*

2.2.1 *Vibrocoring Operations*

In order to accurately represent the characteristics of sediments lying along the full length of the vertical profile of sediments to be dredged it was necessary to use a vibrocoring device for sediment collection. A 3m long, 0.1m diameter, rigid plastic (PVC) sample tube was used to collect sample cores. Sediment samples approximately 10m to 15m below seabed was obtained from vibrocoring. From each vibrocore, sub-samples were extracted for sediment chemistry.

Vibrocoring operations were conducted from a purpose-built drilling vessel. The vessels were equipped with at least one drilling tower, four mooring winches, hydraulic power pack and generator. The vessel was supported by a tug for moving and positioning purposes and a general purpose transport vessel, usually a sampan. The vibrocoring vessel was anchored at the vibrocore position by a four point anchor spread.

2.2.2 *Positioning at Vibrocore Stations*

The receiving antenna was fixed to the top of the drilling mast and connected to the DGPS receiver via electrical connections. This allowed the exact coordinates of the drilling mast to be measured by DGPS. Using the coordinates measured by the DGPS system and displayed by the receiver, the barge was moved close to the vibrocore station to be drilled and the anchors are let down. The anchor lines were adjusted (tightened or released) until the coordinates of the drilling mast as measured by the DGPS system coincided with the coordinates of the vibrocore station. The positioning of the vibrocore station was within 5m of the specified coordinates as given in *Figure 1.1b*. Once the drilling mast was at the desired location, the anchors were locked in place and drilling proceeded.

2.2.3 *Determination of Seabed Levels*

Distance between water surface and seabed surface was determined by hand soundings. Sounding results were related to tide tables or tide gauge results to obtain more precise estimates.

2.2.4 *Vibrocore System*

The vibrocore system comprised of a vibrocore barrel, 3m long and 0.1m in diameter, connected by heavy duty drill rods to a hydraulic vibrator operated from the deck of the marine vessel. The vibrocore barrel was fitted with a removable rigid PVC liner. A basket core catcher and, if necessary, a piston was fitted in the barrel assembly to aid core recovery. The hydraulic vibrator was capable of varying the vibration energy. The vibrocore barrel was lowered to the seabed on the drill string which was connected to the hydraulic vibrator. The hydraulic vibrator was attached to two vertical guide wires within the drill tower and was free to move vertically in response to barge movements due to swell. The vibrocore barrel was driven into the seabed by hydraulic vibration. When the required sample depth has been penetrated the barrel was retrieved and the PVC liner removed.

2.2.5 *Taking of Vibrocores, Sampling Mixing and Storage*

Following the guidance of *WBTC 22/92*, cores were sampled at seabed surface to the interface of marine deposit and alluvium. *Figure 2.2a* provides a schematic diagram of vibrocore sampling protocols.

Subsamples, each 100 to 200mm thick, were removed from depths of 0.00m, 0.90m, 1.90m, 2.9m, and then at 3m intervals to the base of the sample (see *Figure 2.2a*) for sediment chemistry analysis. Sediment within each subsample was mixed thoroughly in order to produce a homogeneous composite. Stainless steel spoon and bowl were used and the mixing was done rapidly so as to reduce the sediment's exposure to air. Each subsample contained approximately 0.78 to 1.5 litres of sediment. The subsampled sediments were stored in a clean solvent-washed glass jar with Teflon-lined lid for sediment chemistry tests.

Each glass jar containing sediment samples was put into a polypropylene plastic bag. All samples (in jars and bags) were double-bagged and labelled internally and externally with indelible ink for date, station number, sample length, diameter and depth. They were then inventoried and logged on chain-of-custody forms. All samples were packed in cooler boxes and cooled to 4°C for shipment. Chain-of-custody forms detailed all information relevant to the samples, including sample location, date and time of sampling, identification of sample, identification of responsible personnel, unique sample identifier and signatures. Sediment samples were extracted within 7 days and analysed within 14 days.

The remaining vibrocore was sealed, fitted with rubber caps, taped and placed in core boxes. For logging and photographing of the vibrocore samples a section of the plastic tube was cut away along the entire length to expose the recovered sediment, and photographs have been taken of all the recovered materials. These photographs are presented in the Final Fieldwork Report[2] prepared by Bachy Soletanche.

2.2.6 *Sample Description*

The materials encountered in the vibrocores are generally in agreement with the description of Sheet 14 (Cheung Chau - Edition 1, 1995) of the 1:20,000 HGM20 Series geological map of Hong Kong. The sequence of strata encountered is summarised as follows:

- Marine Deposit (Hang Hau Formation) was encountered in all vibrocores and generally comprised dark greenish grey, sandy silty clay with shell fragment.
- Alluvium was encountered in all vibrocores except at station S13 and mainly comprised brownish grey, sandy silty clay with occasional subangular fine to medium gravel.

The vibrocores were terminated at the alluvium layer. Detailed descriptions of the vibrocore samples are provided in the Final Fieldwork Report prepared by Bachy Soletanche.

2.3 SEDIMENT CHEMISTRY ANALYSES

2.3.1 *Sediment Sample Analysis*

Sediment chemistry analyses were conducted for the sediment samples for the heavy metals including Cd, Cr, Cu, Hg, Ni, Pb and Zn. The laboratory analysis of the sediment samples were carried out by Materialab Limited which is accredited for the testings of the seven heavy metals under the HOKLAS scheme. The methods and detection limits applied in the sediment chemistry analysis are summarized in *Table 2.3a*.

Table 2.3a ***Detection Limits of Sediment Chemistry Analysis (mg kg^{-1} dry weight)***

Analyte	Minimum Detection Limit	Analytical Method
Cadmium	0.5	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.
Chromium	5	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.

(2) Bachy Soletanche Group (August 1998). Final Fieldwork Report, Contract No 98/8229 Lamma Power Station Extension Sediment Sampling and Testing.

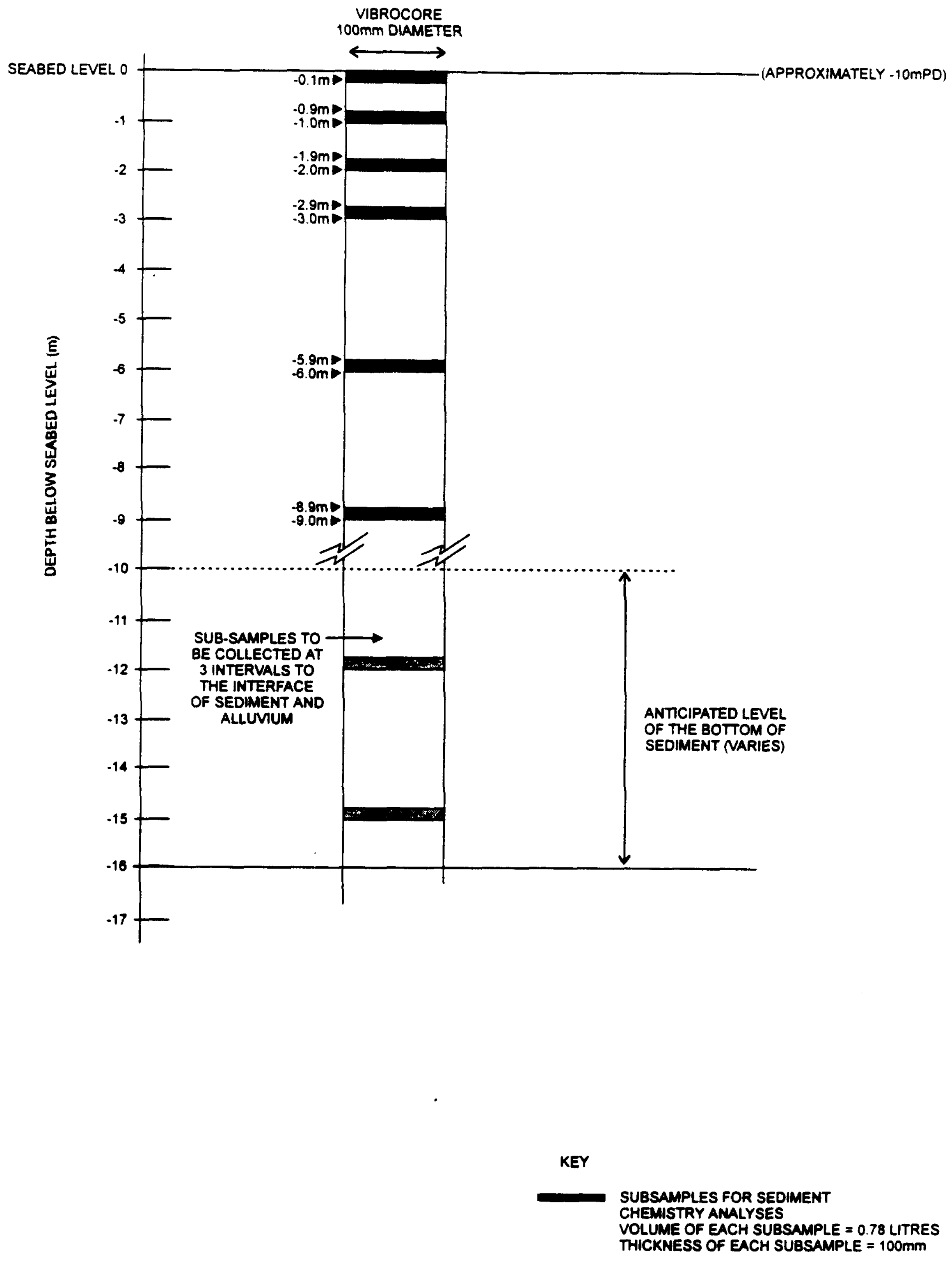

FIGURE 2.2a SCHEMATIC DIAGRAM OF VIBROCORES AND THEIR SUBSAMPLES

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Analyte	Minimum Detection Limit	Analytical Method
Copper	10	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.
Mercury	0.4	APHA, 18th Ed, 3122B Samples was digested with a mixture of potassium permanganate, sodium persulfate, sulphuric acid and nitric acid solution. The mercury content in the digested solution was analysed by cold-vapour atomic abortion spectrometric method.
Nickel	6	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.
Lead	15	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.
Zinc	15	ASTM D3974-81 (1990) Samples was digested with a mixture of nitric acid and hydrochloric acid solution. The digested solution was analysed by atomic absorption spectrometry.

2.4 *Quality Assurance/Quality Control*

2.4.1 *Quality Control Measures for on-Site Sample Collection*

The positioning of the vibrocore station was within 5m of the specified coordinates by DGPS. The depth of water to seabed surface at each sampling point was determined prior to vibrocoring.

The minimum sample recovery was 80% of the vibrocore length. If the required recovery was not achieved, another vibrocore sample was taken at the adjacent location.

The top 10mm of sediment of each 100mm vibrocore sample was removed using a stainless steel spoon. The spoon was thoroughly washed with clean fresh water. Subsample was taken from the centre of the core using the stainless steel spoon. The sediment at the outer ring (about 10mm) of the core was not collected. The subsampled sediment was stored in a clean solvent-washed glass jar with Teflon-lined lid for sediment chemistry analysis. The jar will be labelled with indelible ink for date, station number, sample length, diameter and depth. Each glass jar containing the sediment samples was put into a labelled plastic bag. The subsamples were immediately stored at 4°C in a cooler box prior to delivery to the testing laboratory. Samples were delivered to the laboratory within 12 hours after sampling with a chain-of custody form.

All the sampling tools were thoroughly cleaned using clean fresh water before taking the next subsample to avoid cross contamination.

2.4.2 *Quality Assurance & Quality Control Measures for Laboratory Analysis*

Quality control procedures was applied to this testing programme which involved laboratory blanks, batch duplicates and Standard Reference Material.

- sample testing was conducted with duplicate at a 5% level (ie for every 20 samples, one sample should be tested in duplicate); and
- each batch of samples was tested along with a Standard Reference Material of marine sediment and a Blank sample for checking of accuracy.

2.4.3 *Standard Reference Materials*

Certified reference materials were ran with each batch of samples in order to further monitor the recovery of metals from the various sample types (*Table 2.4a*). The reference material used comprised SETOC 701[3] for sediment.

Table 2.4a ***Standard Reference Materials Tested with each Batch of Samples***

Analyte	**Standard Reference Material**
	Acceptance Range of SETOC 701 (mg kg^{-1})
Cadmium, Cd	1.81 - 2.17
Chromium, Cr	73.1 - 89.3
Copper, Cu	79.9 - 100.9
Lead, Pb	151 - 163
Nickel, Ni	29.6 - 38.0
Zinc, Zn	492 - 558
Mercury, Hg	1.07 - 1.25

[3] SETOC 701 is a reference material sample used in proficiency test program of Wageningen Evaluating Programmes for Analytical Laboratories (WEPAL).

3 SEDIMENT CHARACTERISATION

3.1 CLASSIFICATION CRITERIA

Dredged sediments destined for marine disposal are classified according to their level of contamination by seven toxic metals as stipulated in the EPD *Technical Circular (EPD TC) No. 1-1-92, Classification of Dredged Sediments for Marine Disposal*. The seven criteria metals are Cd, Cr, Cu, Hg, Ni, Pb, and Zn. The contamination levels presented in the *EPD TC 1-1-92* serve as criteria for determining the disposal requirements of marine dredged sediments. Definition of the classification is as follows:

- *Class A:* Uncontaminated material, for which no special dredging, transport or disposal methods are required beyond those which would normally be applied for the purpose of ensuring compliance with EPD's Water Quality Objectives (WQO), or for protection of sensitive receptors near the dredging or disposal areas.

- *Class B:* Moderately contaminated material, which requires special care during dredging and transport, and which must be disposed of in a manner which minimizes the loss of pollutants either into solution or by resuspension.

- *Class C:* Seriously contaminated material, which must be dredged and transported with great care, which cannot be dumped in the gazetted marine disposal grounds and which must be effectively isolated from the environment upon final disposal.

EPD's criteria for the classification of dredged sediments destined for marine disposal are given in *Table 3.1a*. Permits from the EPD are required for marine disposal of such materials.

Table 3.1a ***Classification of Sediments by Metal Content (mg kg^{-1} dry weight)***

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Class A	0.0-0.9	0-49	0-54	0.0-0.7	0-34	0-64	0-149
Class B	1.0-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-199
Class C	1.5 or more	80 or more	65 or more	1.0 or more	40 or more	75 or more	200 or more

It should be noted that sediments which exceed the Class C level for any of the seven heavy metals are categorised as Class C. Conversely, to be classified as suitable for unconfined open water disposal, sediments must be below the Class C for all seven heavy metals. The final classification decision and selection of appropriate disposal options, routing and the allocation of a permit to dispose at the designated disposal site will be made by the EPD, in consultation with the Fill Management Committee (FMC) in accordance with *WBTC 22/92* and *6/92*.

3.2 SAMPLING & TESTING RESULTS

3.2.1 *Sediment Sampling*

The sediment sampling was conducted between 23 July 1998 to 29 July 1998. The findings of the fieldworks are presented in the *Final Fieldwork Report* prepared by Bachy Soletanche. *Table 3.2a* summarises the strata depths and thickness at the sampling locations.

Table 3.2a ***Summary of Strata Depths and Thickness***

Location	Easting	Northing	Seabed Level (mPD)	Marine Deposit	
				Levels (mPD)	Thickness (m)
S1	828650.00	808500.00	-10.82	-10.82 to -21.62	10.80
S2	828650.00	808300.00	-10.98	-10.98 to -25.18	14.20
S3	828650.00	808100.00	-10.01	-10.01 to -23.61	13.60
S4	828650.00	807900.00	-13.13	-13.13 to -22.13	9.00
S5	828850.00	808500.00	-10.22	-10.22 to -26.62	16.40
S6	828850.00	808300.00	-9.77	-9.77 to -23.17	13.40
S7	828850.00	808100.00	-9.48	-9.48 to -22.98	13.50
S8	828850.00	807900.00	-9.51	-9.51 to -22.41	12.90
S9	829050.00	808499.00	-9.10	-9.10 to -24.10	15.00
S10	829050.00	808300.00	-8.38	-8.38 to -22.88	14.50
S11	829050.00	808100.00	-8.36	-8.36 to -20.16	11.80
S12	829050.00	807900.00	-8.90	-8.90 to -21.80	12.90
S13	829250.00	808500.00	-7.65	-7.65 to -19.65	12.00
S14	829249.68	808300.00	-8.53	-8.53 to -20.53	12.00
S15	829250.00	808100.00	-8.44	-8.44 to -22.74	14.30
S16	829250.00	807900.00	-8.55	-8.55 to -20.55	12.00

3.2.2 *Sediment Testing*

Sediment Sample Testing

Sediment samples were analysed for the seven heavy metals (including Cu, Cd, Cr, Pb, Ni, Zn and Hg). The details of the laboratory results are given in *Annex B8-1b* and summarised in *Table 3.2b*.

Table 3.2b ***Summary of Sediment Sampling Results (mg kg^{-1} Dry Weight)***

Location	Cu	Cd	Cr	Pb	Ni	Zn	Hg	Classification
S1	<10	<0.5	19-31	20-21	<6-20	27-72	<0.4	A
S2	<10-20	<0.5	25-36	20-39	14-22	65-87	<0.4	A
S3	<10-20	<0.5	26-36	<15-35	16-22	59-79	<0.4	A
S4	<10-21	<0.5	31-34	20-33	18-30	64-85	<0.4	A
S5	<10-23	<0.5	8-32	<15-36	<6-19	17-85	<0.4	A
S6	<10-24	<0.5	27-36	<15-36	17-21	54-86	<0.4	A
S7	<10-24	<0.5	19-46	<15-24	11-30	42-130	<0.4	A
S8	<10-20	<0.5	26-42	20-33	16-23	48-78	<0.4	A
S9	<10-10	<0.5	8-33	<15-22	<6-20	28-74	<0.4	A
S10	<10-10	<0.5	8-36	<15-28	<6-23	18-75	<0.4	A
S11	<10	<0.5	17-38	<15-21	7-21	33-76	<0.4	A
S12	<10-20	<0.5	11-35	<15-33	<6-22	<15-79	<0.4	A
S13	<10	<0.5	7-33	<15-21	<6-20	<15-75	<0.4	A
S14	<10-10	<0.5	18-35	<15-33	11-23	58-77	<0.4	A
S15	<10-10	<0.5	17-33	<15-27	<6-23	<15-75	<0.4	A
S16	<10-10	<0.5	26-35	<15-26	15-22	52-76	<0.4	A

Note:
(a) For details of sediment quality for each sampling depth, see *Annex B8-1b*

Quality Control Sample

Table 3.2c ***Blank Samples Testing Results (mg l^{-1})***

Sample Identification	Batch No.	Cu	Cd	Cr	Pb	Ni	Zn	Hg
Blank Sample	1	<0.05	<0.01	<0.05	<0.05	<0.05	0.02	<0.001
	2	<0.05	<0.01	<0.05	<0.05	<0.05	0.02	<0.001
	3	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	4	<0.05	<0.01	<0.05	<0.05	<0.05	0.04	<0.001
	5	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	6	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	7	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001

Table 3.2d ***Reference Material Testing Results (mg kg^{-1} Dry Weight)***

Sample Identification	Batch No.	Cu	Cd	Cr	Pb	Ni	Zn	Hg
Reference Material SETOC 701	1	87.7	2.09	80.1	153	34.2	519	1.17
	2	87.4	2.09	82.1	158	34.0	527	1.11
	3	89.6	2.14	83.1	153	33.6	501	1.11
	4	90.0	2.09	77.3	155	33.7	502	1.15
	5	85.4	2.04	82.1	155	34.0	516	1.16
	6	89.7	2.10	82.6	153	34.7	516	1.13
	7	84.4	2.04	77.8	158	35.4	512	1.18

4 CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

Based on the analytical results of the sediments and the *EPD Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal*, the marine sediments at all vibrocore stations and at full depth of the sediment column within the proposed dredging area for the 1,800MW Gas-fired Power Station at Lamma Extension contain low levels of heavy metals and is classified as Class A (uncontaminated) sediment.

4.2 RECOMMENDATIONS

The engineering approach to forming the reclamation is being evaluated by the Engineering Consultants, Binnie Black & Veatch HK Limited. A number of alternatives to dredging are being considered. One of the principal objectives of the design is to minimise the amount of sediment to be dredged and disposed of. Should dredging of marine mud is required, engineering justification for the dredging proposal will be provided. The quantity of marine sediment to be dredged and the rates of disposal of sediment will be submitted to EPD and FMC for approval.

As the sediment in the proposed reclamation area is classified as Class A, it is recommended that they should be disposed of at the south Cheung Chau or the east of Ninepines disposal sites.

Annex B8-1a

Sediment Quality Data of Recent Maintenance Dredging Works Near Lamma Power Station

Table 1 Results of Analysis of Sediment Cores

Sample Identification		Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of Contamination Level (*)
Borehole No.	Depth								
A	0.00-0.10m	10	<0.5	25	26	9	65	<0.4	Class A
A	0.80-1.00m	10	<0.5	32	20	17	73	<0.4	Class A
A	1.90-2.00m	10	<0.5	36	20	20	82	<0.4	Class A
A	2.90-3.00m	10	<0.5	36	21	20	81	<0.4	Class A
A	5.90-6.00m	10	<0.5	38	20	22	80	<0.4	Class A
B	0.00-0.10m	<10	<0.5	13	<15	<6	37	<0.4	Class A
B	0.80-0.90m	10	<0.5	14	20	8	40	<0.4	Class A
B	1.80-2.00m	10	<0.5	35	20	19	78	<0.4	Class A
B	2.90-3.00m	10	<0.5	36	21	20	77	<0.4	Class A
B	5.90-6.00m	10	<0.5	38	21	21	80	<0.4	Class A
C	0.00-0.10m	23	<0.5	27	29	13	74	<0.4	Class A
C	0.90-1.00m	<10	<0.5	25	20	12	61	<0.4	Class A
C	1.90-2.00m	10	<0.5	36	21	19	76	<0.4	Class A
C	2.90-3.00m	10	<0.5	36	20	22	77	<0.4	Class A
C	5.90-6.00m	10	<0.5	36	21	21	79	<0.4	Class A
D	0.00-0.10m	20	<0.5	25	29	14	64	<0.4	Class A
D	0.90-1.00m	10	<0.5	40	22	24	86	<0.4	Class A
D	1.90-2.00m	10	<0.5	41	22	23	90	<0.4	Class A
D	2.80-3.00m	10	<0.5	36	20	20	62	<0.4	Class A
D	5.90-6.00m	10	<0.5	37	20	20	65	<0.4	Class A
E	0.00-0.10m	10	<0.5	34	24	17	73	<0.4	Class A
E	0.90-1.00m	<10	<0.5	30	<15	17	62	<0.4	Class A
E	1.90-2.00m	<10	<0.5	33	20	19	72	<0.4	Class A
E	2.90-3.00m	10	<0.5	34	20	19	73	<0.4	Class A
E	5.90-6.00m	10	<0.5	38	20	21	76	<0.4	Class A
F	0.00-0.10m	10	<0.5	30	24	14	70	<0.4	Class A
F	0.90-1.00m	<10	<0.5	32	<15	18	66	<0.4	Class A
F	1.90-2.00m	<10	<0.5	36	20	21	76	<0.4	Class A
F	2.90-3.00m	10	<0.5	36	20	20	80	<0.4	Class A
F	5.80-6.00m	10	<0.5	36	20	20	74	<0.4	Class A
G	0.00-0.10m	<10	<0.5	27	20	14	58	<0.4	Class A
G	0.90-1.00m	<10	<0.5	32	<15	17	65	<0.4	Class A

Sample Identification		Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of Contamination Level (*)
Borehole No.	Depth								
G	1.90-2.00m	<10	<0.5	35	20	19	72	<0.4	Class A
G	2.90-3.00m	10	<0.5	36	20	20	76	<0.4	Class A
G	5.90-6.00m	10	<0.5	42	20	23	83	<0.4	Class A
H	0.00-0.20m	24	<0.5	35	29	17	81	<0.4	Class A
H	0.90-1.00m	10	<0.5	41	20	22	81	<0.4	Class A
H	1.90-2.00m	10	<0.5	43	20	23	81	<0.4	Class A
H	2.90-3.00m	10	<0.5	41	20	24	79	<0.4	Class A
H	5.90-6.00m	10	<0.5	39	20	21	70	<0.4	Class A

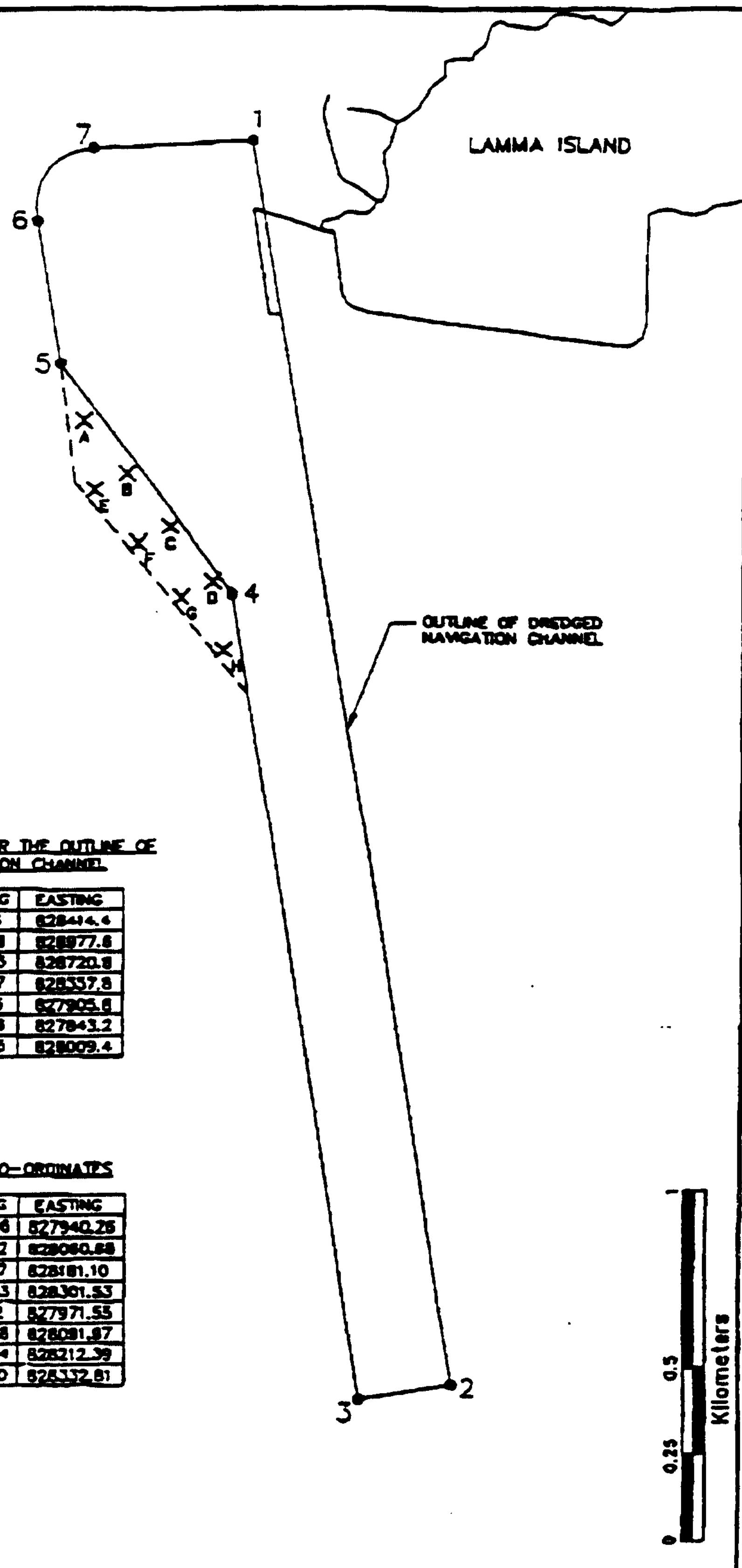
Remarks: *1. Results are based on mass of sample dried at 103-105°*

2. Testings of the seven heavy metals contents of sediment are accredited by HOKLAS.

** The classification of contamination level of sediment is an opinion of the laboratory, based on the following table issued by EPD and is not covered under the HOKLAS accreditation*

Table 2 Classification of Sediments by Metal Content (mg/kg/dry weight)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Class A	0.0-0.9	0-49	0-54	0.0-0.7	0-34	0-64	0-140
Class B	1.0-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-190
Class C	1.5 or more	80 or more	65 or more	1.0 or more	40 or more	75 or more	200 or more



CO-ORDINATES FOR THE OUTLINE OF DREDGED NAVIGATION CHANNEL

POINT	NORTHING	EASTING
1	809101.5	828414.4
2	805545.9	828977.6
3	805605.3	828720.8
4	807796.7	828337.8
5	808413.5	827905.6
6	808808.6	827843.2
7	809037.5	828009.4

SAMPLING POINT CO-ORDINATES

POINT	NORTHING	EASTING
A	808307.86	827940.26
B	808154.62	828060.68
C	808001.57	828181.10
D	807848.53	828301.53
E	808110.12	827971.55
F	807957.08	828091.97
G	807804.04	828212.39
F	807651.00	828332.81

Hyder Consulting

THE HONG KONG ELECTRIC CO LTD
LAMMA POWER STATION JETTY EXTENSION

MARINE SEDIMENT
SAMPLING AND TESTING

Scale: AS SHOWN
Date: OCT 97
LAMMA.DRG
FIGURE 1

Annex B8-1b

Laboratory Analysis Results

BACHY
SOLETANCHE

CONTRACT NO. 98/8229
LAMMA POWER STATION EXTENSION
SEDIMENT SAMPLING AND TESTING

FINAL LABORATORY REPORT

Volume I : Heavy Metals

AUGUST 1998

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TSIM SHA TSUI
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Table of content

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MateriaLab

Our Ref. No. : 981625EN80528

HOKLAS REGISTRATION NO.15

I. Introduction

MateriaLab Ltd. was commissioned by the Client, Bachy Soletanche Group, to provide laboratory analysis services on sediment samples submitted by the Client. MateriaLab was responsible for provision of man-power, equipment and other supplies for satisfactory execution of the above activities.

II. Test requirement and method statement

1. Cadmium, chromium, copper, nickel, lead and zinc content
   - Sample was digested with mixture of nitric acid and hydrochloric acid followed by determination using atomic absorption spectrometer.
2. Mercury content
   - Sample was digested with mixture of potassium permanganate, sodium persulfate, sulphuric acid and nitric acid followed by determination using atomic absorption spectrometer with cold vapor technique.

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MateriaLab

III. Results

Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S1 0.00-0.20m	<10	<0.5	26	21	17	64	<0.4	A
S1 0.00-0.20m (duplicate)	<10	<0.5	25	21	17	64	<0.4	A
S1 0.90-1.10m	<10	<0.5	28	20	18	67	<0.4	A
S1 1.90-2.10m	<10	<0.5	30	20	20	71	<0.4	A
S1 2.80-3.00m	<10	<0.5	30	20	20	71	<0.4	A
S1 5.80-6.00m	<10	<0.5	31	20	20	72	<0.4	A
S1 8.80-9.00m	<10	<0.5	30	20	20	66	<0.4	A
S1 11.20-11.40m	<10	<0.5	19	20	<6	27	<0.4	A
S2 0.00-0.20m	10	<0.5	25	27	14	66	<0.4	A
S2 0.90-1.10m	<10	<0.5	28	20	19	65	<0.4	A
S2 1.90-2.10m	<10	<0.5	29	20	18	70	<0.4	A
S2 2.80-3.00m	<10	<0.5	31	20	20	74	<0.4	A
S2 5.80-6.00m	<10	<0.5	33	20	20	73	<0.4	A
S2 8.80-9.00m	10	<0.5	34	20	22	74	<0.4	A
S2 11.80-12.00m	10	<0.5	33	20	22	71	<0.4	A
S2 14.80-15.00m	20	<0.5	36	39	21	87	<0.4	A

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Our Ref. No. : 981625EN80528

HOKLAS REGISTRATION NO.15

Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S3 0.00-0.20m	10	<0.5	26	22	16	64	<0.4	A
S3 0.90-1.10m	<10	<0.5	27	<15	18	64	<0.4	A
S3 1.90-2.10m	<10	<0.5	30	20	18	73	<0.4	A
S3 2.80-3.00m	<10	<0.5	30	20	19	71	<0.4	A
S3 5.80-6.00m	10	<0.5	36	21	22	76	<0.4	A
S3 5.80-6.00m (duplicate)	10	<0.5	33	22	21	75	<0.4	A
S3 8.90-9.00m	<10	<0.5	30	18	20	64	<0.4	A
S3 11.90-12.00m	<10	<0.5	28	23	17	59	<0.4	A
S3 14.90-15.00m	20	<0.5	31	35	19	79	<0.4	A
S4 0.00-0.20m	10	<0.5	31	24	18	74	<0.4	A
S4 0.90-1.10m	10	<0.5	34	21	20	75	<0.4	A
S4 1.90-2.10m	<10	<0.5	34	23	20	69	<0.4	A
S4 2.80-3.00m	10	<0.5	32	20	18	69	<0.4	A
S4 5.80-6.00m	10	<0.5	34	33	21	70	<0.4	A
S4 8.90-9.00m	10	<0.5	32	28	19	64	<0.4	A
S4 11.55-11.65m	21	<0.5	33	28	30	85	<0.4	A

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Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S5 0.00-0.20m	23	<0.5	32	36	17	85	<0.4	A
S5 0.90-1.10m	<10	<0.5	24	24	16	64	<0.4	A
S5 1.90-2.10m	<10	<0.5	29	20	19	68	<0.4	A
S5 2.80-3.00m	<10	<0.5	29	20	18	69	<0.4	A
S5 5.80-6.00m	<10	<0.5	28	20	17	66	<0.4	A
S5 8.80-9.00m	<10	<0.5	18	<15	11	42	<0.4	A
S5 11.80-12.00m	<10	<0.5	22	20	14	47	<0.4	A
S5 14.80-15.00m	10	<0.5	22	34	16	72	<0.4	A
S5 17.80-18.00m	<10	<0.5	8	20	<6	17	<0.4	A
S5 17.80-18.00m (duplicate)	<10	<0.5	9	20	<6	17	<0.4	A
S6 0.00-0.20m	24	<0.5	34	35	20	86	<0.4	A
S6 0.90-1.10m	10	<0.5	30	29	17	67	<0.4	A
S6 1.90-2.10m	<10	<0.5	28	<15	19	60	<0.4	A
S6 2.80-3.00m	<10	<0.5	31	20	19	69	<0.4	A
S6 5.80-6.00m	10	<0.5	36	21	21	78	<0.4	A
S6 8.80-9.00m	10	<0.5	34	21	21	75	<0.4	A
S6 11.80-12.00m	<10	<0.5	27	20	17	54	<0.4	A
S6 14.80-15.00m	20	<0.5	35	36	21	80	<0.4	A

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Our Ref. No. : 981625EN80528

HOKLAS REGISTRATION NO 15

Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S7 0.00-0.20m	<10	<0.5	19	20	11	42	<0.4	A
S7 0.90-1.10m	<10	<0.5	31	24	19	69	<0.4	A
S7 1.90-2.10m	<10	<0.5	30	20	20	65	<0.4	A
S7 2.80-3.00m	<10	<0.5	33	20	21	78	<0.4	A
S7 5.80-6.00m	<10	<0.5	32	20	20	130	<0.4	A
S7 8.90-9.00m	24	<0.5	37	21	20	88	<0.4	A
S7 11.90-12.00m	<10	<0.5	25	<15	15	47	<0.4	A
S7 14.90-15.00m	10	<0.5	46	24	30	82	<0.4	A
S8 0.00-0.20m	10	<0.5	34	33	18	78	<0.4	A
S8 0.90-1.10m	<10	<0.5	30	22	19	67	<0.4	A
S8 0.90-1.10m (duplicate)	<10	<0.5	31	21	19	69	<0.4	A
S8 1.90-2.10m	<10	<0.5	28	20	17	62	<0.4	A
S8 2.80-3.00m	<10	<0.5	31	20	18	69	<0.4	A
S8 5.80-6.00m	<10	<0.5	32	21	19	70	<0.4	A
S8 8.90-9.00m	<10	<0.5	26	20	16	48	<0.4	A
S8 11.90-12.00m	<10	<0.5	33	21	20	63	<0.4	A
S8 14.90-15.00m	20	<0.5	34	20	23	68	<0.4	A
S8 15.88-15.95m	10	<0.5	42	22	23	73	<0.4	A

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Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S9 0.00-0.20m	<10	<0.5	24	<15	15	51	<0.4	A
S9 0.90-1.10m	<10	<0.5	25	15	15	55	<0.4	A
S9 1.90-2.10m	<10	<0.5	29	20	17	63	<0.4	A
S9 2.80-3.00m	<10	<0.5	33	20	19	74	<0.4	A
S9 5.80-6.00m	<10	<0.5	32	20	20	72	<0.4	A
S9 8.80-9.00m	<10	<0.5	12	<15	7	28	<0.4	A
S9 11.80-12.00m	<10	<0.5	26	20	15	48	<0.4	A
S9 14.80-15.00m	10	<0.5	28	22	16	56	<0.4	A
S9 17.80-18.00m	<10	<0.5	8	<15	<6	32	<0.4	A
S10 0.00-0.20m	<10	<0.5	8	<15	<6	18	<0.4	A
S10 0.90-1.10m	10	<0.5	30	28	18	73	<0.4	A
S10 0.90-1.10m (duplicate)	10	<0.5	30	28	18	74	<0.4	A
S10 1.90-2.10m	<10	<0.5	29	<15	18	64	<0.4	A
S10 2.80-3.00m	<10	<0.5	30	20	19	66	<0.4	A
S10 5.80-6.00m	<10	<0.5	28	20	17	67	<0.4	A
S10 8.80-9.00m	10	<0.5	36	21	21	75	<0.4	A
S10 11.80-12.00m	<10	<0.5	18	<15	10	36	<0.4	A
S10 14.80-15.00m	10	<0.5	31	21	23	70	<0.4	A

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Our Ref. No. : 981625EN80528

HOKLAS REGISTRATION NO 15

Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S11 0.00-0.20m	<10	<0.5	28	20	19	64	<0.4	A
S11 0.90-1.10m	<10	<0.5	31	20	17	69	<0.4	A
S11 1.90-2.10m	<10	<0.5	34	20	21	75	<0.4	A
S11 2.80-3.00m	<10	<0.5	36	21	21	76	<0.4	A
S11 5.80-6.00m	<10	<0.5	34	20	20	75	<0.4	A
S11 8.80-9.00m	<10	<0.5	38	20	21	70	<0.4	A
S11 11.80-12.00m	<10	<0.5	28	<15	15	51	<0.4	A
S11 13.40-13.60m	<10	<0.5	17	<15	7	33	<0.4	A
S12 0.00-0.20m	20	<0.5	32	33	16	79	<0.4	A
S12 0.90-1.10m	<10	<0.5	31	22	18	67	<0.4	A
S12 1.90-2.10m	<10	<0.5	29	<15	17	63	<0.4	A
S12 2.80-3.00m	<10	<0.5	30	20	18	67	<0.4	A
S12 2.80-3.00m (duplicate)	<10	<0.5	28	20	18	63	<0.4	A
S12 5.80-6.00m	<10	<0.5	33	21	21	77	<0.4	A
S12 8.90-9.00m	10	<0.5	34	20	22	72	<0.4	A
S12 11.90-12.00m	10	<0.5	35	20	21	76	<0.4	A
S12 14.80-14.90m	<10	<0.5	11	<15	<6	<15	<0.4	A

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HOKLAS REGISTRATION NO.15

Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S13 0.00-0.20m	<10	<0.5	27	20	17	64	<0.4	A
S13 0.90-1.10m	<10	<0.5	27	20	16	62	<0.4	A
S13 1.90-2.10m	<10	<0.5	32	20	19	73	<0.4	A
S13 2.80-3.00m	<10	<0.5	33	21	20	75	<0.4	A
S13 5.80-6.00m	<10	<0.5	15	<15	9	29	<0.4	A
S13 8.80-9.00m	<10	<0.5	7	<15	<6	<15	<0.4	A
S13 11.80-12.00m	<10	<0.5	10	<15	<6	20	<0.4	A
S14 0.00-0.20m	10	<0.5	21	33	11	63	<0.4	A
S14 0.90-1.10m	<10	<0.5	27	20	17	58	<0.4	A
S14 1.90-2.10m	<10	<0.5	28	20	17	65	<0.4	A
S14 2.80-3.00m	<10	<0.5	29	20	17	67	<0.4	A
S14 5.80-6.00m	10	<0.5	34	22	21	77	<0.4	A
S14 8.80-9.00m	10	<0.5	35	21	21	76	<0.4	A
S14 11.80-12.00m	<10	<0.5	18	<15	11	42	<0.4	A
S14 11.80-12.00m (duplicate)	<10	<0.5	18	<15	11	42	<0.4	A
S14 14.80-15.00.	10	<0.5	30	30	23	57	<0.4	A

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Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S15 0.00-0.20m	10	<0.5	17	21	10	51	<0.4	A
S15 0.90-1.10m	10	<0.5	29	27	19	75	<0.4	A
S15 1.90-2.10m	<10	<0.5	25	<15	17	60	<0.4	A
S15 2.80-3.00m	<10	<0.5	28	20	18	64	<0.4	A
S15 5.80-6.00m	<10	<0.5	33	20	21	75	<0.4	A
S15 8.80-9.00m	<10	<0.5	32	20	23	72	<0.4	A
S15 11.80-12.00m	<10	<0.5	24	<15	15	49	<0.4	A
S15 14.80-15.00m	<10	<0.5	18	<15	<6	<15	<0.4	A

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Sample Identification	Copper Content mg/kg	Cadmium Content mg/kg	Chromium Content mg/kg	Lead Content mg/kg	Nickel Content mg/kg	Zinc Content mg/kg	Mercury Content mg/kg	Classification of contamination level (*)
S16 0.00-0.20m	10	<0.5	30	26	18	73	<0.4	A
S16 0.90-1.10m	<10	<0.5	30	20	19	67	<0.4	A
S16 1.90-2.10m	<10	<0.5	30	20	18	69	<0.4	A
S16 2.80-3.00m	<10	<0.5	31	20	19	73	<0.4	A
S16 5.80-6.00m	<10	<0.5	35	20	22	76	<0.4	A
S16 8.90-9.00m	<10	<0.5	33	20	21	72	<0.4	A
S16 11.90-12.00m	<10	<0.5	31	20	19	74	<0.4	A
S16 14.90-15.00m	10	<0.5	26	<15	15	52	<0.4	A

Remarks :
1. Results are based on mass of sample dried at 103-105°C.
2. A copy of works order and a sketch of sampling location are appendix in the Appendix.
3. Testings of the seven heavy metals contents of sediment are accredited by HOKLAS.

* The classification of contamination level of sediment is an opinion of the laboratory, based on the following table issued by EPD and is not covered under the HOKLAS accreditation

Table 1 - Classification of Sediments by Metal Content (mg/kg dry weight)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Class A	0.0-0.9	0-49	0-54	0.0-0.7	0-34	0-64	0-140
Class B	1.0-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-190
Class C	1.5 or more	80 or more	65 or more	1.0 or more	40 or more	75 or more	200 or more

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Our Ref. No. : 981625EN80528

HOKLAS REGISTRATION NO 15

QC Results :

Sample identification	Batch No.	Copper content (mg/L)	Cadmium content (mg/L)	Chromium content (mg/L)	Lead content (mg/L)	Nickel content (mg/L)	Zinc content (mg/L)	Mercury content (mg/L)
Blank sample	1	<0.05	<0.01	<0.05	<0.05	<0.05	0.02	<0.001
	2	<0.05	<0.01	<0.05	<0.05	<0.05	0.02	<0.001
	3	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	4	<0.05	<0.01	<0.05	<0.05	<0.05	0.04	<0.001
	5	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	6	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001
	7	<0.05	<0.01	<0.05	<0.05	<0.05	<0.02	<0.001

Sample identification	Batch No.	Copper content (mg/kg)	Cadmium content (mg/kg)	Chromium content (mg/kg)	Lead content (mg/kg)	Nickel content (mg/kg)	Zinc content (mg/kg)	Mercury content (mg/kg)
Reference Material SETOC 701	1	87.7	2.09	80.1	153	34.2	519	1.17
	2	87.4	2.09	82.1	158	34.0	527	1.11
	3	89.6	2.14	83.1	153	33.6	501	1.11
	4	90.0	2.09	77.3	155	33.7	502	1.15
	5	85.4	2.04	82.1	155	34.0	516	1.16
	6	89.7	2.10	82.6	153	34.7	516	1.13
	7	84.4	2.04	77.8	158	35.4	512	1.18
Control range (mg/kg)		79.9-100.9	1.81-2.17	73.1-89.3	151-163	29.6-38.0	492-558	1.07-1.25

Supervised by : K.F. Wong

Certified by : [signature]
Approved Signatory : K.M. Ho

Date : 13/8/98

Annex B10 - 1

Input Parameters for MDS Plots

Table B10-1-1 Input Parameters for MDS Analysis of Results from the Intertidal Surveys at the West Coastal Sites

Site	Chiton	Limpet	Snail	Barnacle	Bivalve	Algae
T1a	34	1144	115	584	0	364
T1b	106	230	416	602	4	219
T1c	26	1379	354	855	0	205
T2a	18	1528	101	255	269	283
T2b	35	493	139	1130	206	1131
T2c	42	1005	84	1078	365	1035
T3a	15	734	121	1268	110	700
T3b	66	964	182	689	100	236
T3c	15	1080	172	628	133	637
T4a	21	701	154	896	61	426
T4b	37	743	19	608	61	422
T4c	19	194	242	618	79	798
T5a	25	365	262	504	63	273
T5b	29	373	109	555	46	342
T5c	77	471	78	514	89	220
T6a	80	639	135	527	33	622
T6b	128	485	120	649	37	287
T6c	95	455	123	510	39	694

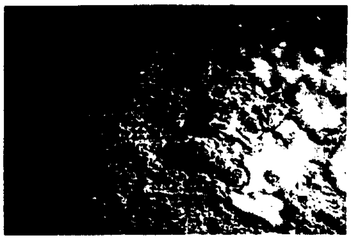
Table B10-1-2 Input Parameters for MDS Analysis of Results from the Subtidal Surveys at the West Coastal Sites

Site	Decapoda	Gastropoda	Bivalvia	Echinodermata	Coral	Sponge	Other Invertebrates	Algae	Non-living Material
T1a	2	24	1	1	5	3	85	0	7
T1b	3	78	11	3	2	0	37	0	61
T1c	1	66	12	9	2	0	17	0	81
T1d	0	0	0	0	0	0	0	0	100
T1e	4	4	4	0	2	0	10	8	80
T1f	1	19	21	1	0	0	0	0	100
T2a	26	121	83	6	0	0	5	0	15
T2b	24	96	70	4	3	0	0	0	21
T2c	54	58	50	3	0	0	0	0	12
T2d	34	34	61	6	2	0	0	0	29
T2e	3	0	1	1	0	0	0	0	30
T2f	9	18	0	1	2	0	0	0	43
T3a	9	43	0	2	0	0	85	0	15
T3b	25	11	0	0	0	0	100	0	0
T3c	24	15	0	0	0	0	98	2	0
T3d	31	17	6	1	0	0	80	0	15
T3e	0	0	0	1	0	0	5	0	95
T3f	35	36	23	13	0	0	37	0	40
T4a	28	122	50	6	0	0	45	0	5
T4b	34	67	28	10	0	0	60	0	12
T4c	32	81	38	4	0	0	60	0	2
T4d	17	94	7	10	0	0	87	0	7
T4e	23	46	3	3	0	2	90	0	5

Site	Decapoda	Gastropoda	Bivalvia	Echinodermata	Coral	Sponge	Other Invertebrates	Alage	Non-living Material
T4f	17	33	5	3	0	0	87	0	8
T5a	45	30	1	4	0	0	100	0	0
T5b	17	30	18	7	0	2	38	0	42
T5c	15	6	1	17	0	0	37	0	64
T5d	33	2	10	46	0	0	53	0	38
T5e	19	89	0	7	0	0	100	0	0
T5f	9	229	0	3	0	0	100	0	0
T6a	39	181	10	3	2	0	97	2	0
T6b	24	133	10	51	0	0	83	17	0
T6c	38	347	11	23	2	2	95	2	0
T6d	35	353	0	20	2	3	27	66	2
T6e	23	235	5	54	0	0	70	25	0
T6f	8	175	4	96	0	0	62	36	2

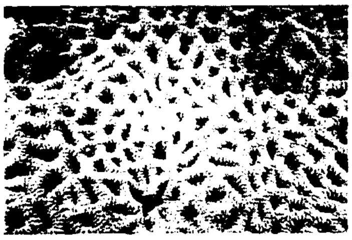
Annex B10 - 2

Representative Substrates or Organisms of Interest Recorded During the Subtidal Surveys at the West Coastal Sites

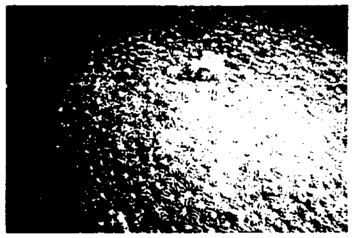


ENCRUSTING GREY SPONGE IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 0.5%

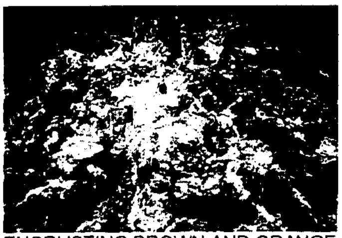
ENCRUSTING GREY SPONGE IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 0.5%



ENCRUSTING HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 1.5%



ENCRUSTING HARD CORAL (FAMILY FAVIIDAE)IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 1.5%

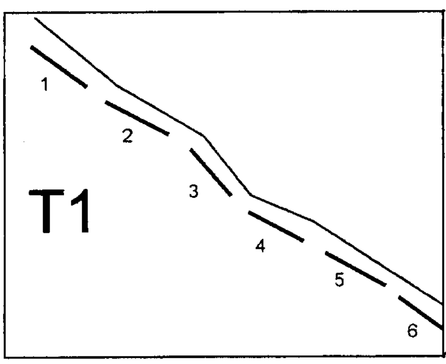


ENCRUSTING BROWN AND ORANGE SPONGE IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 0%

ENCRUSTING HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 1.5%

SAND AND SHELL DEBRIS IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 61%

ENCRUSTING HARD CORAL *COSCINAREA COLUMNA* IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 0%



TRANSECT PLAN ON SITE T1

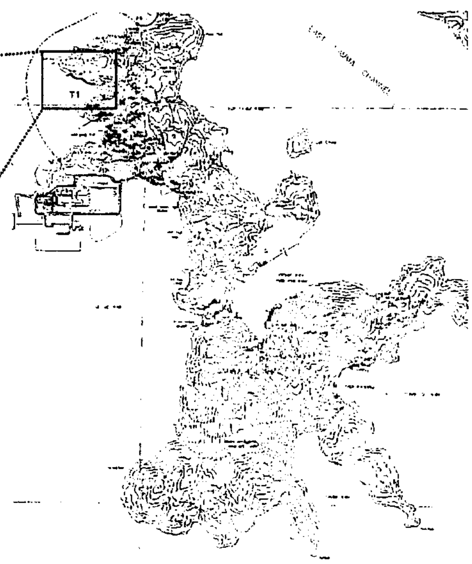


FIGURE B1

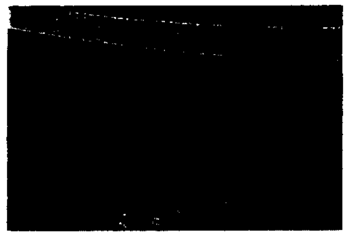
REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBESERVED WITHIN THE BELT TRANSECTS AT WEST COASTAL SITE T1

Environmental Resources Management

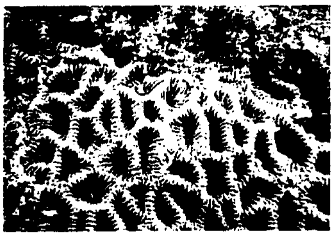
ERM

FILE: C1830/C1830i1
DATE: 30/09/98

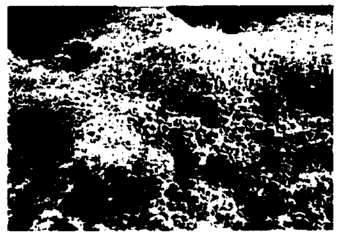
ROCK ENCRUSTED WITH THE MUSSEL, *SEPTIFER VIRGATUS* IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 41%



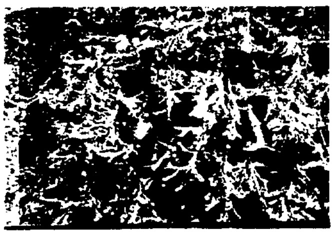
SAND AND DEBRIS IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 29%



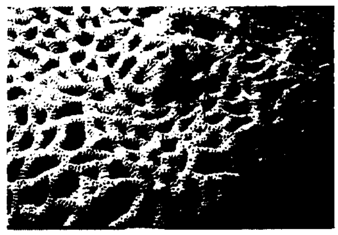
HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 1.2%



FILAMENTOUS TURF ALGAE IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 0%



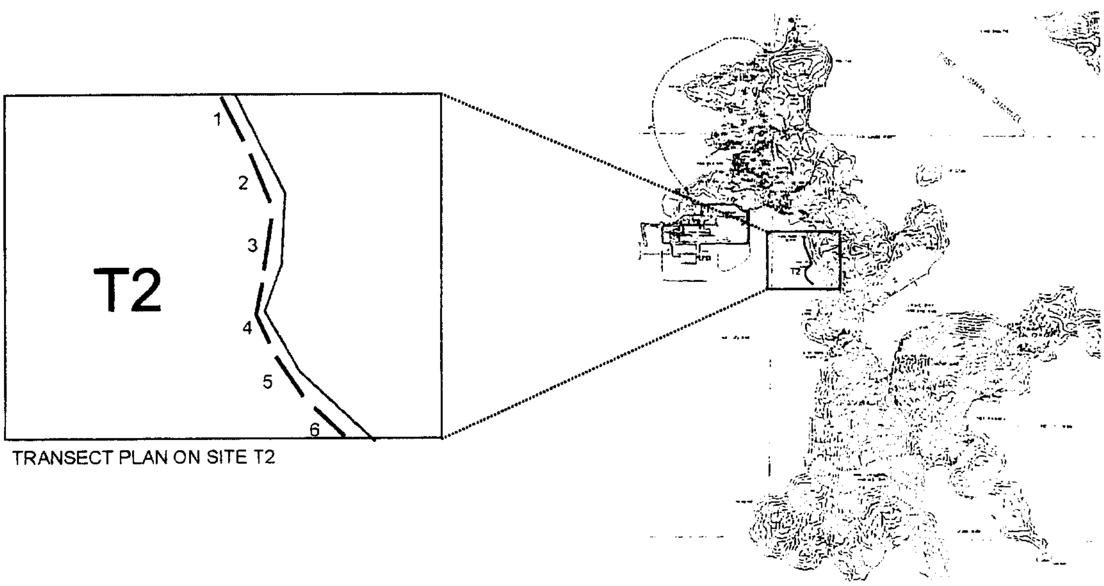
ERECT CORALLINE ALGAE IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 41%



HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 1.2%

FILAMENTOUS TURF ALGAE IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 0%

ROCK ENCRUSTED WITH THE BARNACLE *BALANUS* SPP AND DOGWHELKS IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 21%



TRANSECT PLAN ON SITE T2

FIGURE B2

REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBSERVED WITHIN THE BELT TRANSECTS AT WEST COASTAL SITE T2

Environmental Resources Management

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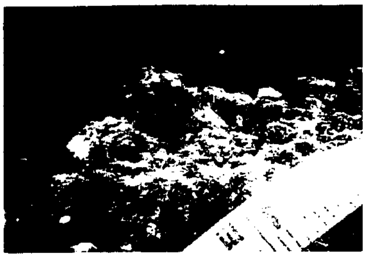
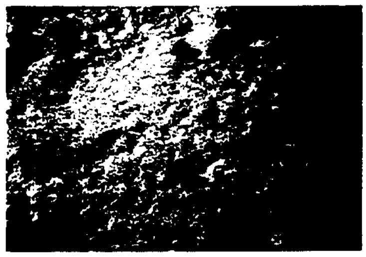
FILE: C1830/C1830i5
DATE: 30/09/98



ROCK ENCRUSTED WITH THE BARNACLE *BALANUS* SPP, IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 67.5%

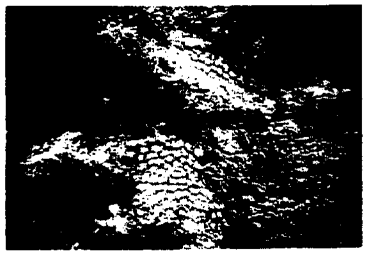


ENCRUSTING SPONGE, IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 0%

ROCK ENCRUSTED WITH THE MUSSEL, *PERNA VIRIDIS*, IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 0%

ENCRUSTING HARD CORAL *COSCINAREA COLUMNA*, IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 0%

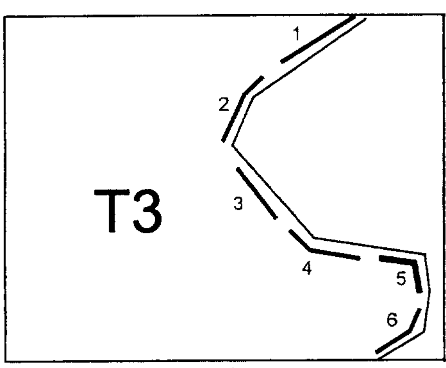
ROCK ENCRUSTED WITH THE BARNACLE *BALANUS* SPP, AND GASTROPOD EGGS, IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 67.5%



HARD CORAL (FAMILY FAVIIDAE), IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 0%

ROCK ENCRUSTED WITH THE BARNACLE *BALANUS* SPP, IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 67.5%

ENCRUSTING BROWN AND ORANGE SPONGE, IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 0%



TRANSECT PLAN ON SITE T3

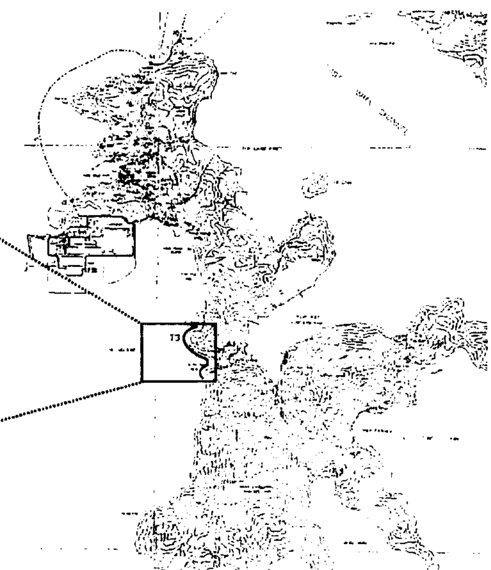


FIGURE B3

REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBSERVED WITHIN THE BELT TRANSECTS AT WEST COAST SITE T3

Environmental Resources Management

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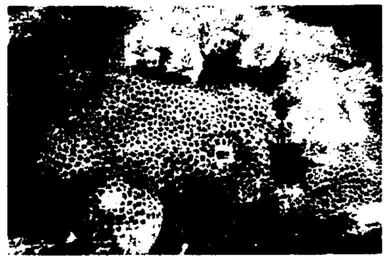
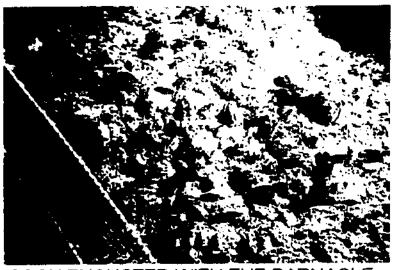
FILE: C1830/C1830i6

DATE: 30/09/98

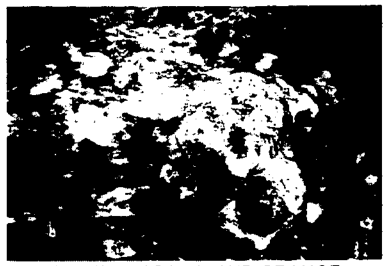
ROCK ENCUSTED WITH THE BARNACLE *BALANUS* SPP, IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 71.5%



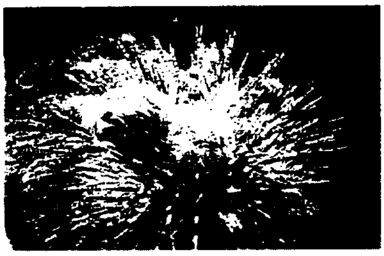
ENCRUSTING HARD CORAL (FAMILIY FAVIIDAE), IN BELT TRANSECT 5. MEAN COVER FROM LINE TRANSECTS = 0%



ROCK ENCUSTED WITH THE BARNACLE *BALANUS* SPP, AND THE MUSSEL, *SEPTIFER VIRGATUS* IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 71.5%



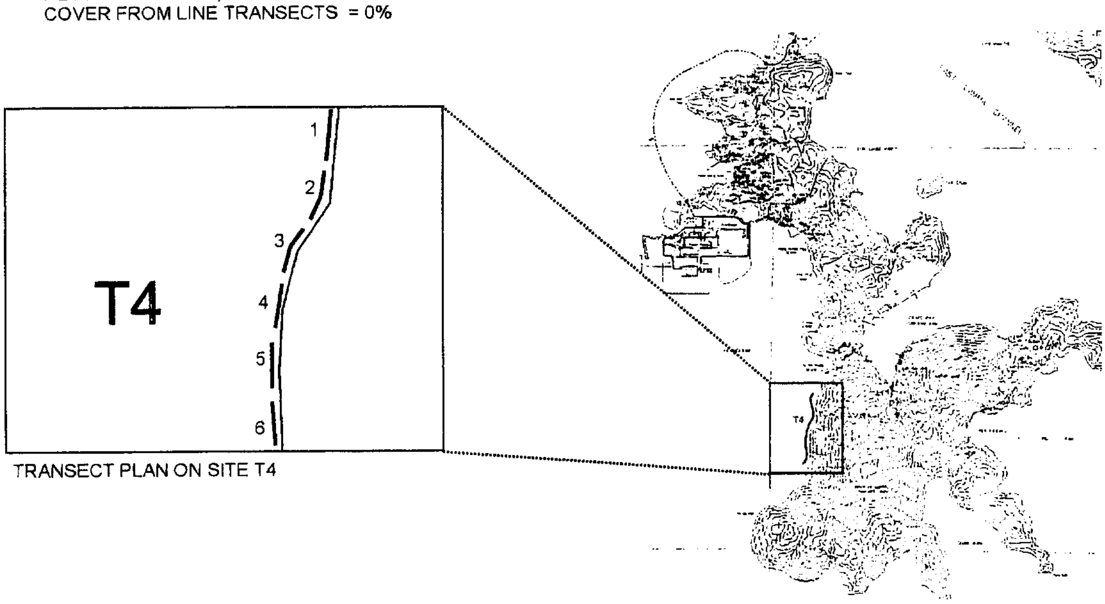
ENCRUSTING BROWN AND ORANGE SPONGE IN BELT TRANSECT 5. MEAN COVER FROM LINE TRANSECTS = 0.3%



THE SEA URCHIN, *SALMACIS SPHAEROIDES* IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 0%

BARE ROCK COVERED WITH SEDIMENT IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 0%

ROCK ENCRUSTED WITH CORALLINE ALGAE, *PEYSONNELIA* SPP, IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 0%



TRANSECT PLAN ON SITE T4

FIGURE B4

REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBSERVED WITHIN THE BELT TRANSECTS AT WEST COAST SITE T4

Environmental Resources Management

ERM

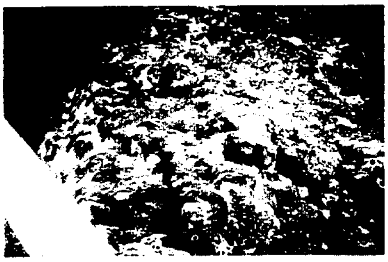
FILE: C1830/C1830I7
DATE: 30/09/98

DAMSEL FISH, *CHROMIS NOTATUS* IN BELT TRANSECT 1.

ROCK ENCRUSTED WITH BARNACLE *BALANUS* SPP, IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 71%

SEA CUCUMBER *COLOCHIRUS CRASSUS* IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 0%

SAND AND SHELL DEBRIS IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 24%

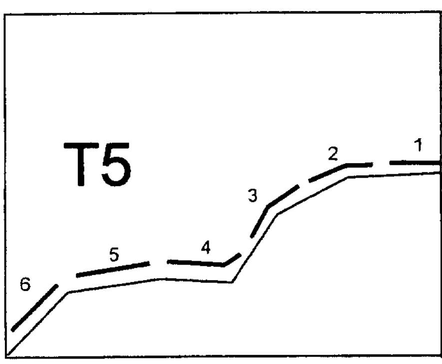


ENCRUSTING BROWN AND ORANGE SPONGE IN BELT TRANSECT 2.

ROCK ENCRUSTED WITH BARNACLE *BALANUS* SPP, IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 71%

ROCK ENCRUSTED WITH BARNACLE *BALANUS* SPP, IN BELT TRANSECT 1. MEAN COVER FROM LINE TRANSECTS = 71%

ROCK ENCRUSTED WITH BARNACLE *BALANUS* SPP, IN BELT TRANSECT 5. MEAN COVER FROM LINE TRANSECTS = 71%



TRANSECT PLAN ON SITE T5

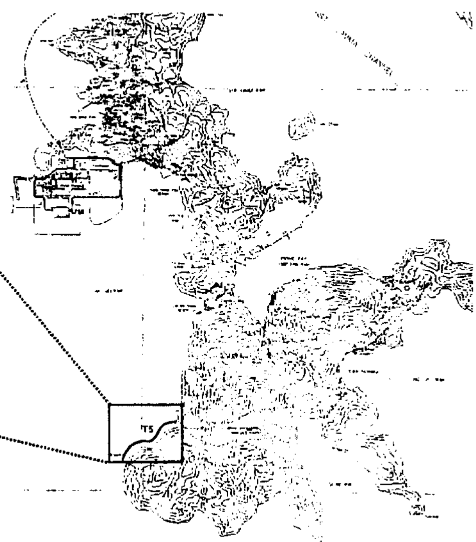


FIGURE B5

REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBSERVED WITHIN THE BELT TRANSECTS AT WEST COAST SITE T5

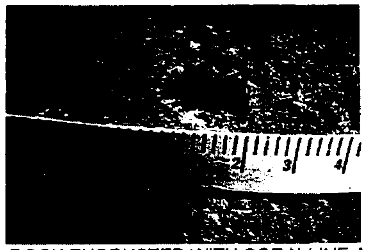
Environmental Resources Management

ERM

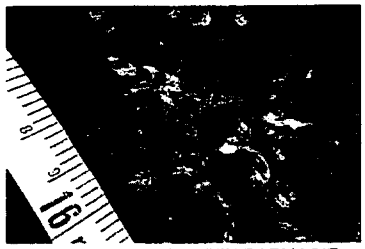
FILE: C1830/C1830I8

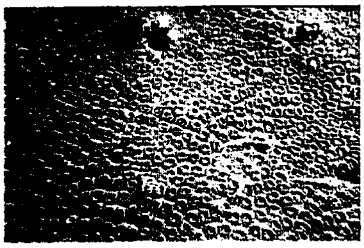
DATE: 30/09/98


ENCRUSTING HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 4. MEAN COVER FROM LINE TRANSECTS = 1%

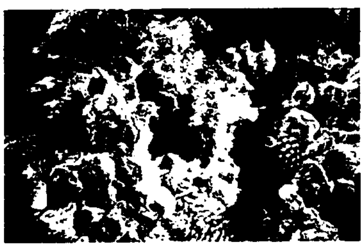

ROCK ENCRUSTED WITH CORALLINE ALGAE, *PEYSONNELIA* SPP, IN BELT TRANSECT 6. MEAN COVER FROM LINE TRANSECTS = 11%

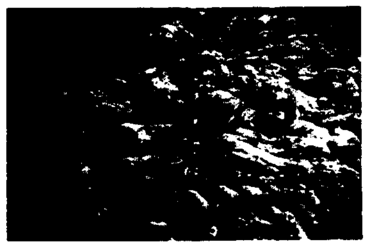

ENCRUSTING HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 5. MEAN COVER FROM LINE TRANSECTS = 1%

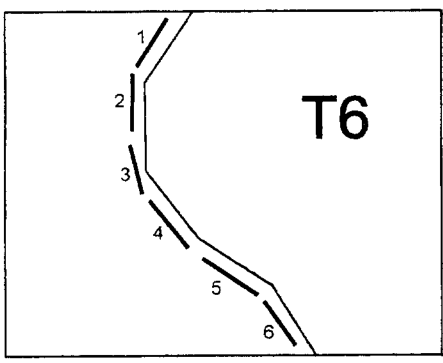

ROCK ENCRUSTED WITH BARNACIE *BALANUS* SPP, IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 72%


ENCRUSTING HARD CORAL (FAMILY FAVIIDAE) IN BELT TRANSECT 5. MEAN COVER FROM LINE TRANSECTS = 1%


ROCK ENCRUSTED WITH BARNACIE *BALANUS* SPP, NOTE MORAY EEL, *GYMNOTHORAX UNDULATUSIN* BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 72%


ROCK ENCRUSTED WITH BARNACLES *BALANUS* SPP, NOTE GASTROPOD EGGS, IN BELT TRANSECT 3. MEAN COVER FROM LINE TRANSECTS = 72%


ENCRUSTING BROWN AND ORANGE SPONGE IN BELT TRANSECT 2. MEAN COVER FROM LINE TRANSECTS = 0.8%



TRANSECT PLAN ON SITE T6

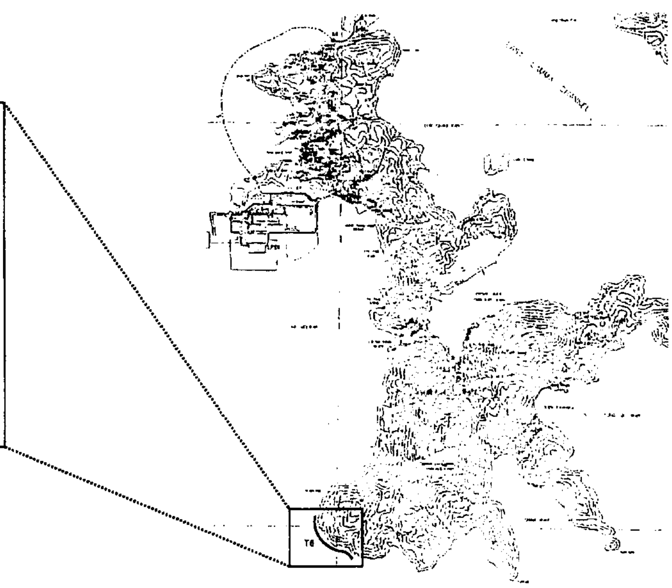


FIGURE B6

REPRESENTATIVES OF SUBSTRATES AND ORGANISMS OF INTEREST OBSERVED WITHIN THE BELT TRANSECTS AT WEST COAST SITE T6

Environmental Resources Management

ERM

FILE: C1830/C183019
DATE: 30/09/98

Annex B10 - 3

Statistical Analysis of the Impact of Heated Effluent on Intertidal Rocky Shores on the Coast of Lamma Island

ANNEX B10-3: STATISTICAL ANALYSIS OF THE IMPACT OF HEATED EFFLUENT ON INTERTIDAL ROCKY SHORES ON THE COAST OF LAMMA ISLAND

Statistical Techniques

Observed differences in the structure of intertidal assemblages were examined using analysis of variance (ANOVA). Differences were examined with a two-factor ANOVA with the factors "site" and "transect" fixed and with the factor "transect" nested within "site". The factor transect has been nested within area because we are interested in differences between sites but are not interested in comparisons between transects in different sites (ie transect A at T1 versus transect C at T6) as we are already examining differences between the sites (ie T1 versus L4).

Significant main effects were examined using the Student-Newman-Keuls (SNK) multiple comparison procedure to isolate which treatments differ from others. The approach followed here is an internationally recommended technique for use in monitoring programmes and EIAs[1].

For all of the analysis of variance techniques performed during this assessment, initial analyses were performed to ensure that the data were compliant with the specific assumptions of analysis of variance. These assumptions state:

- the data within and among samples must be independent of each other;
- the variance within samples must be equal (tested through the use of the Levene's median test); and
- the data among the samples must be normally distributed (tested through the use of the Kolgomorov-Smirnov test).

As is typical with data gathered during environmental assessments, much of the data failed to agree with the latter two assumptions. When this was the case, appropriate transformations were used (detailed separately for each parameter) and the data re-tested for compliance with the assumptions. If no appropriate transformation could achieve compliance then the data was tested using non-parametric procedures.

As the analyses were conducted using ANOVA with more than one factor, a decision was made when the hypotheses were constructed as to which factors should be fixed and which should be random. Fixed factors are those which are concerned with specific identifiable treatments (eg specified areas or specified times such as months or seasons), whereas random factors are those concerned with a general problem, some components of which are included (representatively) in the assessment (eg increases in a broad area with samples taken from randomly chosen locations from within that area). Because the sampling programme involves specifying sampling within *a priori* predicted

(1) AJ Underwood (1997) Experiments in Ecology: their logical design and interpretation using analysis of variance.

impact areas (eg Landing & Launching Points), the factors "site" and "transect" were considered to be fixed. Sampling was conducted only during the wet season for all sites as dry season samples were only necessary for the Landing and Launching Points. Therefore, temporal effects were not examined.

The construction of hypotheses which require analyses using a fixed factor model infers the adoption of a more precautionary approach in this assessment. The detection of significant differences requires less power when using a fixed factor model than a random factor model as the analyses utilise the degrees of freedom associated with the residual term (the highest degrees of freedom) as the denominator in the test. The denominator in a random factor model will be one of the other specified factors in the test and consequently will have a lower degrees of freedom. A fixed factor model will have much lower critical *F* values than a random factor model and is more likely to detect a significant difference.

Results

Observed differences between the sites T1 - T6 and additionally those surveyed at the landing and launching points (L1 - L4) were analysed using analysis of variance techniques. Although significant differences were observed between sites for all of the tested parameters (abundance of snails, abundance of limpets and abundance of chitons, percentage cover of algae, and percentage cover of barnacles) there were no consistent patterns that inferred a relationship between temperature elevated water and the tested parameters.

For example, the percentage cover of algae was lowest at site T1 in Yung Shue Wan bay an area that experiences a 2°C elevation in water temperature as a result of the discharges. However the percentage cover of algae did not differ significantly (using the multiple comparison procedure) with sites L1, which is close to the existing power station and experiences elevations of 4°C, and T5 which is located to the far south of the power station at Ha Mei Tsui and experiences only a 1°C elevation.

Results of Two Factor Nested Analysis of Variance Student Newman Keuls Multiple Comparison Procedures

Dependent Variable: Percentage Cover of Algae

Transformation = Square Root and Arc Sin

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	18.590(b)	29	0.641	11.694	0	0.557
Intercept	127.143	1	127.143	2319.296	0	0.896
SITE	10.32	9	1.147	20.918	0	0.411
TRANSECT(SITE)	8.27	20	0.413	7.543	0	0.358
Error	14.801	270	5.48E-02			
Total	160.535	300				
Corrected Total	33.391	299				
a	Computed using alpha = .05					
b	R Squared = .557 (Adjusted R Squared = .509)					

Student-Newman-Keuls

SITE	N	Subset 1	2	3	4	5
1	30	0.3636				
7	30	0.4164				
5	30	0.477	0.477			
3	30		0.5637	0.5637		
4	30			0.6257	0.6257	
6	30			0.672	0.672	
2	30				0.7547	0.7547
10	30					0.8579
9	30					0.886
8	30					0.893

Dependent Variable: Percentage Cover of Barnacles

Transformation = Square Root and Arc Sin

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	26.085(b)	29	0.899	28.774	0	0.756
Intercept	68.45	1	68.45	2189.69	0	0.89
SITE	19.078	9	2.12	67.811	0	0.693
TRANSECT(SITE)	7.007	20	0.35	11.208	0	0.454
Error	8.44	270	3.13E-02			
Total	102.975	300				
Corrected Total	34.525	299				
a	Computed using alpha = .05					
b	R Squared = .756 (Adjusted R Squared = .729)					

Student-Newman-Keuls

SITE	N	Subset 1	2	3	4	5
8	30	0.03071				
9	30	3071.00				
7	30		0.3848			
2	30		0.4571	0.4571		
10	30		0.4748	0.4748		
3	30			0.5049		
6	30				0.6165	
5	30				0.6447	
4	30				0.6818	
1	30					0.9013

Results of Two Factor Nested Analysis of Variance Student Newman Keuls Multiple Comparison Procedures

Dependent Variable: Abundance of Chitons

Transformation = Log10 (x+1)

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	18.508(b)	29	0.638	6.057	0	0.394
Intercept	72.893	1	72.893	691.785	0	0.719
SITE	13.139	9	1.46	13.855	0	0.316
TRANSECT(SITE)	5.369	20	0.268	2.548	0	0.159
Error	28.45	270	0.105			
Total	119.851	300				
Corrected Total	46.958	299				
a	Computed using alpha = .05					
b	R Squared = .394 (Adjusted R Squared = .329)					

Student-Newman-Keuls

SITE	N	Subset 1	2	3	4
4	30	0.1905			
3	30	0.239			
2	30	0.3541	0.3541		
1	30	0.3605	0.3605		
5	30	0.3861	0.3861		
9	30		0.5279	0.5279	
6	30			0.605	
8	30			0.7083	0.7083
7	30			0.7083	0.7083
10	30				0.8496

Dependent Variable: Abundance of Limpets

Transformation = Log10 (x+1)

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	26.581(b)	29	0.917	7.219	0	0.437
Intercept	488.388	1	488.388	3846.479	0	0.934
SITE	8.814	9	0.979	7.714	0	0.205
TRANSECT(SITE)	17.767	20	0.888	6.996	0	0.341
Error	34.282	270	0.127			
Total	549.251	300				
Corrected Total	60.863	299				
a	Computed using alpha = .05					
b	R Squared = .437 (Adjusted R Squared = .376)					

Student-Newman-Keuls

SITE	N	Subset 1	2	3
9	30	0.9644		
6	30	1.0715	1.0715	
2	30	1.0922	1.0922	
7	30		1.2617	1.2617
4	30		1.3202	1.3202
8	30		1.3267	1.3267
5	30		1.3325	1.3325
3	30			1.3908
1	30			1.4977
10	30			1.5015

Results of Two Factor Nested Analysis of Variance Student Newman Keuls Multiple Comparison Procedures

Dependent Variable: Abundance of Snails

Transformation = Log10 (x+1)

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	13.865(b)	29	0.478	4.144	0	0.308
Intercept	31.883	1	31.883	276.336	0	0.506
SITE	4.79	9	0.532	4.613	0	0.133
TRANSECT(SITE)	9.075	20	0.454	3.933	0	0.226
Error	31.152	270	0.115			
Total	76.9	300				
Corrected Total	45.017	299				
a	Computed using alpha = .05					
b	R Squared = .308 (Adjusted R Squared = .234)					

Student-Newman-Keuls

SITE	N	Subset 1	2	3
10	30	0.0619		
9	30	0.1253	0.1253	
8	30		0.3069	0.3069
4	30		0.3274	0.3274
3	30		0.3466	0.3466
6	30		0.3642	0.3642
7	30			0.3993
1	30			0.4151
5	30			0.4561
2	30			0.4571

Code	*Survey Site*
Site 1	T1
Site 2	T2
Site 3	T3
Site 4	T4
Site 5	T5
Site 6	T6
Site 7	L1
Site 8	L2
Site 9	L3
Site 10	L4